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PREFACE TO THE SEVENTEENTH EDITION

The changes in this edition have been so extensive as to require a resetting of the entire text. These may be classified as follows: 1. Minor changes in the subject matter; 2. A rearrangement of certain portions of the book; 3. The abridgment of certain sections, and 4. The addition of a large amount of new material.

The net result of these changes has been to increase the book by about 150 pages. The needs of both the engineer in the field and the student have been kept in mind in the work of revision.

In Chapters I, II, IV, V, VI, X, XVIII and XIX while the changes made are few, they are nevertheless important. There may be specially mentioned: the organization of the engineer corps; a section on metric curves; work on paper location. The discussion of the Valvoid has been retained. This subject, while somewhat difficult, admits of great possibilities in the field.

Chapter III has been rewritten. The principles here given have played and are playing an important part in the proper selection of grades and curves.

Chapter VII, Reversed Curves, Chapter IX, The Spiral Curve, Chapter XIII, Earthwork Tables, Chapter XIV, Earthwork Diagrams, and Chapter XV, Haul and the Mass Diagram, are nearly or entirely new.

Chapter VIII, Turnouts and Crossings, has been rewritten and extended, as likewise Chapter XII, Calculation of Earthwork.

The Chapter on Construction in the previous edition has been separated, and new material added, forming three chapters—Chapter XI, Cross-sections, Chapter XVI, *Construction,* and Chapter XVII, Track Laying.

Acknowledgments are made to: The American Railway Engineering Association for permission to use certain material as noted in the text; to the late A. M. Wellington's "Railway Earthwork," which was the first thorough treatment of Earthwork Diagrams; and to Mr. A. S. Crandon, for assistance on the illustrations and computations. Other acknowledgments in connection with the Tables are made in Preface to Volume II.

W. H. S.
H. C. I.

JULY, 1915.

PREFACE TO EIGHTEENTH EDITION

MANY requests for the inclusion of the American Railway Engineering Association Spiral having been made, it is presented in this edition. While discussing the same curve, the method of treatment is more or less original.

Acknowledgments are due the American Railway Engineering Association for permission to use this form of spiral, and for Tables XLVI and XLIX from the Manual of Recommended Practice. Tables XLV, XLVII and XLVIII have been computed in order to make the spiral easier of application.

OCTOBER, 1918.

PREFACE TO THE FIRST EDITION

Although the modern railway system is but about fifty years old, yet its growth has been so rapid, and the progress in the science of railway construction so great, as to render the earlier technical books on this subject inadequate to the needs of the engineer of to-day.

In the course of his practical experience as a railway engineer, the author was strongly impressed with the want of a more complete hand-book for field use, and finally concluded, at the solicitation of his friends, to undertake the preparation of the present volume.

The aim in this work has been:

First.—To present the general subject of railway field work in a progressive and logical order, for the benefit of beginners.

Second.—To classify the various problems presented, so that they may be readily referred to.

Third.—To embrace discussions of all the more important practical questions while avoiding matters non-essential.

Fourth.—To employ throughout the work a uniform and systematic notation, easily understood and remembered, so that after one perusal the formulas may be intelligible at a glance wherever referred to.

Fifth.—To express the resulting formula of every problem in the shape best adapted to convenient numerical computation.

Sixth.—To furnish a large variety of useful tables, more complete and extended than any heretofore published, especially adapted to the wants of the field engineer.

An elementary knowledge of algebra, geometry and trigonometry on the part of the reader has been taken for granted, as a command of these instrumentalities is deemed essential to the education of the civil engineer. The few reference to mechanics, analytical geometry, optics and the calculus may be assumed correct by those not conversant with these branches.

Many of the problems in curves are new, yet there is hardly one that has not presented itself to the author in the course of his practice. The investigation of the valvoid curve is original, and though the mathematical discussion is somewhat difficult, yet the resulting formulas taken in connection with Table VII, are exceedingly simple and convenient for the solution of a certain class of problems.

The treatment of compound curves is novel and exhaustive. A few general equations are established, which, by slight modifications, solve all the problems that can occur.

No discussion of reversed curves is given, because these are inconsistent with good practice, except in turnouts, under which head they are noticed.

The chapter on leveling includes a discussion of stadia measurements, with practical formulas. The chapter on earthwork contains a review of several methods for calculating quantities, and states the conditions under which these succeed or fail in giving correct results.

Among the tables, numbers 2, 3, 7, 26, 29 and 43 are original. The adoption of versed sines and external secants throughout the work, wherever these would simplify the formulas, rendered necessary the preparation of tables of these functions. The tables of logarithmic versed sines and external secants has been computed from ten-place logarithmic tables of sines and tangents, so that the last decimal is to be relied on, and no pains have been spared to make the table thoroughly accurate.

Tables numbers 1, 4, 5, 6, 8, 9, 14, 22 and 30 have been recalculated, enlarged, and some of them carried to more decimal places than similar tables heretofore published. The intention has been to give one more decimal than usual, so that in any combination of figures the result of calculation might be reliable to the last figure usually required.

The tables which have been compiled and rearranged are numbers 15, 16, 17, 24, 25, 41, 42 and 44. The tables of log sines and tangents here given are the only six-place tables which give the differences correctly for seconds. The table of logarithms of numbers is accompanied by a complete table of proportional parts, which greatly facilitates interpolation for the fifth and sixth figures.

In all the tables, whether new or old, scrupulous care has been taken to make the last figure correct, and the greatest diligence has been exercised by various checks and comparisons to eliminate every error. It is, therefore, hoped and believed that a very high degree of accuracy has been obtained, and that these tables will be found to stand second to none in this respect.

The preparation of this work has extended over several years, as time could be spared to it from other engagements. It is, therefore, the expression of deliberate thought, based on experience, and as such is submitted to the judgment of brother engineers. If it shall prove to have even partially met the aim herein announced, and so shall serve to smooth the way of the ambitious student, or to assist the expert in his responsible duties, the labors of the author will not have been in vain.

WM. H. SEARLES, C.E.

NEW YORK, March 1st, 1880.

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FIELD ENGINEERING

CHAPTER I

RECONNAISSANCE

1. The engineering operations requisite to and preceding the construction of a railroad are in general:

The Reconnaissance,
The Preliminary Survey, and
The Location.

2. *The Reconnaissance* is a general and somewhat hasty examination of the country through which the proposed road is to pass, for the purpose of noting its more prominent features, and acquiring a general knowledge of its topography with reference to the selection of a suitable route. The judicious selection of a route may be a very simple or complex problem, depending on the character of the topography, and more especially on the direction of the streams and ridges as compared with the general direction of the proposed road.

3. A road running along a water-course is most easily located. In this case the choice is to be made merely between the two banks of the stream, or between keeping one bank continuously and making occasional crossings. When the stream is small it will usually be found best to cross it at intervals, the advantage of direct alinement outweighing the cost of bridging; but when the stream is of considerable size the solution of the problem is not so obvious, requiring patient comparison of results in the two cases to determine whether to cross or not, while in the case of the larger rivers crossing may be out of the question.

When there is a choice of sides, both banks should traversed by the engineer on reconnaissance, and while ining in detail the one side he should take a general and co prehensive view of the other. Only thus can he gain a comple knowledge of either side. The points to be considered are t relative value of the property on either side, the number a size of tributary streams and probable cost of crossing then the cost of graduation as affected by the amount and charact of the material to be removed and the liability to land slide the amount and degree of curvature required, and the probable revenues which the road can command. If, in respect t these points, one bank of the stream gives the more favorable result all the way, the question is decided at once; but in case the greater inducements are found on either bank alternately, as usually happens, the propriety of bridging the stream, with the costs and advantages, must be considered as an additional element in the problem.

4. When no water-course offers along which the road may be located, the difficulties of selecting a route are increased, and these usually become greatest when the streams are found to run about at right angles to the direction of the road. Valleys and ridges are to be crossed alternately, involving the necessity of ascending and descending grades, diverting the road from a straight line, and increasing the distance and curvature. The engineer must now seek the lowest points on the ridges, and the highest banks at the stream crossings, in order to reduce as much as possible the total rise and fall, but these points must be so chosen relatively to each other as to admit of their being connected by a grade not exceeding the maximum which may be allowable. The intervening country between summit and stream must usually be carefully examined, even on reconnaissance, to determine where the assumed grade will find sustaining ground at a reasonable expense for graduation and right of way.

In selecting stream crossings, regard should be had not only to the height of the bank, but also to the character of the bottom, its suitability for foundations, and its liability to be washed by the current. The direction and force of the current should be observed, and its behavior during freshets, and the extremes of high and low water ascertained, if possible. An approximate estimate of the cost of bridging may be made.

5. The engineer should not only seek the best ground on the *e first assumed,* but should have an eye to all other possible routes, holding them in consideration pending this accumulation of evidence, and being ready, finally, to adopt that one which promises the greatest ultimate economy. He should be able to read the face of the country like a map, and to carry in his mind a continuous idea or image of any line he is examining, so as to judge with tolerable accuracy of the influence any one portion of the line may have on another as to alinement and grade, even though many miles apart. In the successful prosecution of a reconnaissance he must depend mainly on his own natural tact and a judgment matured by experience.

6. The engineer will bring to his aid in the first place the most reliable maps, and those drawn on the largest scale. The sectional maps of United States surveys will be found very useful when they exist. In addition to these it is often desirable to prepare a map on a scale of one or two inches to a mile, on which will be drawn the principal features of the country to be traversed, such as streams, roads, towns, and the principal ridges, if known, but leaving the further details to be filled in by the engineer as he progresses. Such a map furnishes a correct scale for his sketches, and saves much valuable time, as he has only to sketch what the map does not contain, and occasionally to make corrections when he finds the map to be in error. He also notes on the map the *governing points* of the route, such as the best crossings of streams, ridges, or other roads, and any point where the line will evidently be compelled to pass. He may then indicate the route by a dotted line on the map drawn through the governing points. Having traversed the route in one direction he should retrace his steps, verifying or correcting his observations, and making such further notes as seem important. When in a densely wooded country, with but few openings, it may be impossible for him to get a commanding view from any point that will afford him the necessary information as to the general topography. He must then depend largely upon instrumental observations, taking these more frequently, and noting carefully all details likely to prove useful in future surveys.

7. The instruments required on an extended reconnaissance are the barometer and thermometer, the hand *Locke* level, a pocket or prismatic compass, and a telescop strong field-glass. To these may be added a telemeter for measuring distances at sight, but when good maps are to be had this instrument is seldom needed. So also some portable astronomical instruments are necessary in a new country, for determining latitude and longitude, but would only be a useless incumbrance in a settled district.

8. The mercurial barometer has generally been relied upon for the determination of heights, but owing to its inconvenient dimensions and the danger of breaking, it is now discarded by railroad engineers in favor of the more portable aneroid barometer, except in the case of trans-continental surveys. and when astronomical instruments are to be used also.

9. **The best aneroids** are designed to be self compensating for temperature, so that with a constant atmospheric pressure the reading shall be the same at all temperatures of the instrument. This, however, being a very delicate adjustment, is not always successfully made, so that each instrument is liable to have a small error due to temperature peculiar to itself. This error will be found rarely to exceed one hundredth of an inch, *plus* or *minus*, per change of 10° Fahr., and is frequently much less than this. Just what the error is in a particular instrument may be determined by careful comparison with a standard mercurial barometer at the extremes of temperature, assuming the error found as proportional to the difference of temperature for all intermediate degrees of heat. The error having been determined for any aneroid, it should be applied, with its proper sign, to every reading to obtain the true reading.

The sizes generally used are $1\frac{3}{4}$ and $2\frac{1}{2}$ inches in diameter, respectively, and experience seems to prove that there is no advantage in using larger sizes, but rather the contrary.

10. The ordinary barometric formulas and tables have been prepared with reference to the mercurial barometer. In order that they may apply to the aneroid, it is necessary that the latter should be adjusted to read inches of mercury identically with the mercurial column at the sea level at a temperature of 32° Fahr. But as the aneroid, unlike the mercurial column, requires no correction for latitude, nor for the variation in the force of gravity due to elevation, that portion of *the formula which* provides for such corrections, as well as that *ch provides for* a correction due to the temperature of the

instrument itself, may be omitted when using an aneroid. Thus the general formula is very much simplified, and becomes

$$z = \log \frac{h_1}{h'} 60384.3 \left(1 + \frac{t_1 + t' - 64°}{900}\right)$$

in which h_1 and h' are the readings of the aneroid in inches, and t_1 and t' the readings of a Fahrenheit thermometer at the lower and upper of any two stations respectively, and z is the difference in elevation in English feet of those stations.

To facilitate the calculation of heights by this formula, we may write

$$\text{Log} \frac{h_1}{h'} 60384.3 = [\log h_1 - \log h'] \, 60384.3$$

and since only the *difference* of the logs is required, this will not be affected, if we subtract unity from each. The quantities in Table XV are prepared, therefore, by the formula

$$(\log h - 1) \; 60384.3$$

for every $\frac{1}{100}$ of an inch from 19 inches to 31 inches.

Table XVI contains values of $\frac{t_1 + t' - 64°}{900}$ for every degree of $(t_1 + t')$ from 20° to 200° Fahr.

11. *To find the difference in elevation of any two stations by the tables:*

Take the difference of the quantities corresponding to h_1 and h' in Table XV as an approximation, and for a correction multiply this difference by the coefficient corresponding to $(t_1 + t)$, in Table XVI, adding or subtracting the product according to the sign of the coefficient.

Example.—

	Lower Sta. in.	Upper Sta. in.
Aneroid	$h_1 = 29.92$	$h' = 23.57$
Thermometer	$t_1 = 77°.6$	$t' = 70°.4$
By Table XV for 29.92 we have		28741
for 23.57		22485
	Difference	6256

By Table XVI for $77.6 + 70.4 = 148$ we have $+ .0933$

Then $6256 \times .0933 = 583.6848$

and $6256 + 584 = 6840$ ft. $= z$.—Ans.

12. Certain precautions are to be observed in the use of the aneroid. When the index has been adjusted to a correct reading by means of the screw at its back, it should not be meddled with until it can again be compared with a standard mercurial barometer, and even then some engineers prefer to take note of its error, if any, rather than disturb the aneroid. Again, since the principle of compensation supposes the aneroid to have a uniform temperature throughout its parts, it must be guarded against sudden changes, as otherwise the metallic case will be considerably heated or cooled before the change can affect the inner chamber, thus inducing very erroneous results. The aneroid, therefore, should seldom be taken from its leather case, nor exposed to any radiant heat of sun or fire, nor worn so near the person as to increase its temperature above that of the surrounding atmosphere. If removed to an atmosphere of decidedly different temperature, time must be allowed for the aneroid to be thoroughly permeated by the new degree of heat. The aneroid should be held with the face horizontal while being read; it should be handled carefully, and all concussions avoided, and it should be compared with a standard as often as practicable to make sure that it has suffered no derangement. Observing these precautions, and having a really good aneroid, the engineer should obtain excellent results in the estimation of heights. It has been found that the slight error in compensation, previously alluded to, is subject to a change during the first year or two after the instrument is made, but subsequently it becomes quite permanent.

13. For the purpose of obtaining approximate elevations by a simple inspection of the dial, the modern aneroid is provided with a secondary scale reading hundreds of feet, which is placed outside the scale of inches. It is divided according to the following formula prepared by Prof. Airy:

$$z = 55032 \frac{h_1 - h'}{h_1 + h'} \left(1 + \frac{t_1 + t' - 100^\circ}{1000}\right)$$

in which it is evident that no correction for temperature is required when the *average* temperature of the two stations is 50°. When the two scales are engraved on the same plate the *zero of the scale* of feet is coincident with 31 on the scale of *inches; but in some* aneroids the scales are on two concentric plates, so that the zero of one may be made to coincide with any division of the other, which is in some respects an advantage.

14. The theory of the barometer, as expressed in the above formulas, assumes the atmosphere to be at rest, and its pressure affected only by temperature, whereas, in fact, the pressure at any point is liable to sudden changes due to variations in the force of the wind, the amount of humidity, etc. The best way to eliminate errors due to these causes is to take readings simultaneously at the points the elevations of which are to be compared. For this purpose an assistant should be stationed at some point of known elevation contiguous to the route to be surveyed, and provided with an aneroid similar to that carried by the engineer. The aneroids, time-pieces, and thermometers having been compared at this point, the assistant should record the readings every ten minutes, with the time, temperature, and state of the weather. The engineer will thus have a standard with which to compare his own observations. If the survey is so extended that the same conditions of atmosphere are not likely to be experienced by the two observers, the assistant should be instructed to move forward to a new station at a designated time; or two assistants may be employed, one at each of two stations between which the engineer intends to make a reconnaissance. Even with these precautions no attempt should be made to obtain the elevation of important points during, or just before, or after a storm of wind or rain.

15. When but one aneroid is used the observations at the several stations should be taken as nearly together as possible in point of time, and then repeated in inverse order, taking the mean of the observations at each station, and repeating the whole operation if necessary. Only approximate results can be hoped for, however, with a single instrument, unless the atmospheric conditions are very favorable.

16. The Locke Level is an instrument in which the bubble and the observed object may be seen at the same instant, enabling the operator to keep the instrument horizontal, while holding it in the hand, like an ordinary spy-glass. While quite portable, it enables the observer to define rapidly all visible points of the same elevation as his own, and *estimate* from these the relative heights of other points.

may be made useful in a variety of ways which easily suggest themselves to the engineer in cases where no great precision is required, and where a more elaborate level is not at hand.

17. The Prismatic Compass is a portable instrument with folding sights, in using which the bearing to an object may be read at the same instant that the object is observed. The bearings are read upon a floating card, graduated and numbered from zero to 360°, so that no error can be made in substituting one quadrant for another. The instrument may be held freely in the hand during an observation, though better results are obtained by giving it a firm rest.

CHAPTER II

PRELIMINARY SURVEY

18. A preliminary survey consists in an instrumental examination of the country along the proposed route, for the purpose of obtaining such details of distances, elevations, topography, etc., as may be necessary to prepare a map and profile of the route, make an approximate estimate of the cost of constructing the road, and furnish the data from which to definitely locate the line should the route be adopted. The survey is more or less elaborate, according to circumstances. In case the country is new, or the reconnaissance has been incomplete, or if several routes seem to offer almost equal inducements, the survey will partake somewhat of the nature of a reconnaissance, and will be made more hastily than if but one route is to be examined, and that, perhaps, presenting serious engineering difficulties. The survey is made as expeditiously as possible, consistent with general accuracy, but should not usually be delayed for the sake of precision in matters of minor detail.

19. For preliminary survey the **Corps of engineers** is organized as follows:

A locating engineer, a transitman, two chainmen, one or two axemen, a stakeman, and a topographer, these forming the transit (or compass) party, to which a flagman is sometimes added; a leveler and one or two rodmen, forming the level party; and to these is sometimes added two or three rodmen to assist the topographer.

20. The locating engineer takes charge of the corps, and directs the survey. He ascertains or estimates the value of the lands passed over, the owners' names, and the boundary lines crossed by the line of survey. He examines all streams, and estimates the size and character of the culverts and bridges which they will require; he notices existing bridges, and inquires concerning their liability to be carried away b freshet; he selects suitable sites for bridges, examines the character of the foundations, the direction of the current relatively to that of the line, and considers any probable change in the direction of the current during freshets; he inspects the various soils, rocks, and kinds of timber as they are met with and takes full notes of all these and kindred items in his field book. He not unfrequently assumes in addition the duties of topographer. He should run his line as nearly as may be over the ground likely to be chosen for location, so that the information obtained may be pertinent, and so that the length of the line, the shape of the profile, and the estimate based on the survey may approximate to those of the proposed location. To this end he has due regard to the levels taken, and when they show that the line as run fails to be consistent with allowable grades, he either orders the corps back to some proper point to begin a new line, or makes an offset at once to the better position, or continues the same line with some deflection, simply noting the position and probable elevation of better ground, as in his judgment he thinks best. He should at all times maintain a friendly attitude toward proprietors, and by his polite bearing endeavor to secure their cordial support of the new enterprise. If he is tolerably certain that the location will follow nearly the line of the preliminary survey, he should have with him some blank deeds of right of way, and let these be signed by land-owners while they are favorably disposed. When this cannot be done, a blank form of agreement to allow the surveys and construction of the road to proceed until such time as the terms of right of way may be agreed upon may be made very useful. He also selects quarters for his men, and in case of camping out he directs the movements of the camp equipage.

21. The transitman takes the bearings of the courses run, and makes a record of them, with their lengths, or the numbers of the stations where they terminate. He sees that the axemen keep in line while clearing, and the chainmen while measuring; he takes the bearings of the principal roads and streams, and of property lines when met with. In an open country he may save time by selecting some prominent distant object toward which the chainmen measure without his assistance, while he goes forward and prepares to take the direction of the course beyond. In traversing a forest with not too dense undergrowth, when the line is being run to suit the ground according to a given grade, it is a good plan for the transitman to go ahead of the chainmen as far as he can be seen, select his ground, take his direction by backsight on the last station, and then have the chainmen measure toward him. In this case both he and the head chainman should be provided with a good-sized red and white flag, mounted on a straight pole, to be waved at first to call attention, and afterward held vertically for alinement. Otherwise a flagman must be added to the party, who will select the ground ahead under the instructions of the locating engineer, and toward whom the survey will proceed in the usual manner.

22. The head chainman drags the tape and carries a flag which is put into line at the end of each chain length by the transitman or the rear chainman. It is his duty to know that this flag is in line and that his tape is straight and horizontal before making any measurement, and to show the stakeman where each stake is to be driven. A stake is usually driven at the end of each measured chain length, called a station, though in an open and level country the stakes at the odd stations may be omitted, in which case marking pins are used to indicate the odd stations temporarily. In case there is much clearing to be done the head chainman plants his flag in line, and ranging past it, indicates to the axemen what is to be cut, going a little in advance through the bushes so that they may work toward him. The head chainman should be a quick, active and strong man, with a good eye and a taste for his work, as very much of the real progress of the survey depends upon him.

23. The rear chainman holds his end of the tape firmly at the last stake or pin by his own strength, *not* by means of the stake. He keeps the tally by the pins when they are used, and watches the numbers on the stakes to see that they are correct. The end of a course should always be chosen at the end of a chain, if possible, and if not, then at a 10-foot mark, as thus the labor of plotting the map will be much lessened. The numbering of stations is not recommenced with each new course, but is continued from the beginning to the end of the survey, through all its courses, and if one course ends with a portion of a chain the next course begins with the *remainder* of it. It is the rear chainman's duty to attend t this, holding the proper foot mark at the transit station. Any fraction of a chain measured on the line is called a *plus*, and is counted in feet from the previous station. The length of an offset in the line is never included in the length of the line, but if the line should change its course by a right angle, or more, or less, the numbering would go on as usual.

24. **The axemen** should be accustomed to chopping and clearing, and are, therefore, to be selected in the country rather than the city. They will cut out so much of the underbrush and overhanging branches as may interfere with the sight of the transitman or leveler; but care must be taken not to cut unnecessarily wide, and no tree of considerable size should be felled, except in rare instances. When running by compass, if the transitman goes ahead of the chain, he can always select a position so that no large tree will interfere; or, if the line must be produced and strikes a tree, the transit may be brought up and set close to the tree on the forward side as nearly in line as can be estimated, the slight error in offset being neglected, since the line will be produced parallel to itself by the needle.

25. **The stakeman** prepares and marks the stakes, and drives them at the points indicated by the head chainman. When no clearing is needed, the axemen keep him supplied with stakes, as the rapid progress of the chain will only give him time to drive them. The stakes should be 2 feet long and pointed evenly so as to drive straight, and are blazed or faced on two opposite sides, one of which is marked in red chalk with the number of the station. The stake must be driven vertically, and with the marked face to the *rear*, so that it may be read by the rodman as he follows the line.

26. **The topographer** makes accurate sketches of all features of the country immediately on the line, and extends the sketches as far each side of the line as he can, in a book prepared for the purpose. He must never sketch in advance of the chain, nor in advance of his own position. His work should be done to scale as nearly as possible, using the same scale for distances on the line and at right angles to it. The scale adopted should never be less than that of the map to be made from the sketches. The ruled lines of a field book are usually one quarter of an inch apart, so that the scale

of one line to a station equals about 400 feet to an inch. This is the smallest scale ever used. The scale of two lines to a station is most convenient for general use. Four lines to a station are needed in special cases to show details, as in passing through villages. The scale may be changed from time to time as found necessary, but no two scales should ever be used on the same page. The numbering of the stations up the page indicates the scale of the sketch.

27. When the contours of the surface are required, the topographer may join the level party in order that his estimates of heights and slopes may be corrected by the instrument. He should never draw a mass of contours indiscriminately, but should sketch them as they exist at a uniform vertical interval. This interval may be assumed at 5 feet in a gently rolling country, and at 20 feet in a mountainous one, but an interval of 10 feet will be found most convenient generally. If the topographer accompanies the level he can assume the contours at the even tens of feet in elevation, and mark them so, noting where a contour crosses the surveyed line, and sketching its direction and shape both ways from that point. He will estimate the rate of slope of the ground at right angles to the line as so many feet per hundred, and record it from time to time, noting ascent from the line on either side by "A," and descent by " D." If the slope changes within the limit of the page, the line of change may be sketched and the next slope recorded. When little banks or terraces occur, or bluffs and rocks, which cannot be sufficiently indicated by contours, they should be shown by hatchings, and the height noted. Special care should be taken to sketch roads and houses in their correct positions and dimensions, the latter to be either measured, paced or estimated. The dimensions should also be recorded in numbers. The outline of forests may be shown by a scalloped line, and the kind of timber, and whether dense or scattered, written within the inclosed space. Correct outlines are essential, but no time should be given to shading up a sketch with conventional signs. A single sign, or the name of the thing intended, is all sufficient. Land-owners' and residents' names should be recorded whenever they can be obtained, as well as the names of roads, streams and public buildings.

28. **The leveler** takes charge of the level party and keeps the notes of his work. He reads the rod on benches at turning points to hundredths of a foot and to tenth other points. He should direct a bench to be made at l once every half mile, and in a very rough country ev quarter of a mile. The benches need not be far from the l and, if well chosen, may be used as turning points, thus sav time. The elevation of turning points must be compu when taken, so that the elevation of any one of them may instantly given when called for, and the other elevations be filled in as far as may be without delaying the survey. As the levels are usually the most essential part of the survey, much care should be taken to have the instrument well adjusted and truly level, and the rod held vertically and correctly read on turning points, but the intermediate work should not be so done as to delay the party unnecessarily. The leveler should use every endeavor to follow closely after the surveying party, so that the locating engineer and topographer may have the advantage of his notes.

29. The rodman's first duty is to hold the rod vertically, and he must learn to do this in calm or windy weather, in level field or on side hill. He may carry a small *disk-level*, which applied to the edge of the rod will show when it is vertical. The turning points are to be selected for firmness and definiteness, and so that they will afford a clear view from beyond for a backsight. The rod is held for a reading on the ground at every stake, the number of which is called out to the leveler as soon as the rodman arrives at it; the rod is also to be held at every prominent change of slope on the line, as the crest and foot of every bank, the rodman calling out its distance from the last stake as *plus* so many feet, but all gentle undulations and minor irregularities are to be neglected. The rod will always be read at the surface of a stream or pond, and also at its deepest part on the line, when possible; otherwise the depth of the water may be found by sounding, and so recorded. Should the line run along a stream the surface will be taken occasionally, opposite certain stations, and in case of a canal, the elevation of surface above and below each lock must be noted. The rodman makes inquiry for *high-water marks* or seeks traces of them himself in an uninhabited district, and holds the rod upon them that their elevation may be determined. The rodman carries a small axe or hatchet with which to make benches and to trim out any stray branch that may intercept the leveler's view.

30. Where detailed information is desired on a narrow stretch of country near the preliminary line, one or more rodmen may assist the topographer in securing this. The contours and all important features such as highways, fences, buildings, bodies of water, etc., should be located. A contour may be located either by hand level, level rod and tape, or by horizontal and vertical rods. The first method is probably in more general use, but the second has a decided advantage in the fact that the work may be done independently of the level work. For further information on these two methods see Chapter XVIII on Topographical Sketching.

31. In defining the duties of the members of the corps, the instruments used have been incidentally noticed.

32. The compass is sometimes used instead of the transit on preliminary surveys, because it can be operated more rapidly, is lighter, and usually has a better needle. It may have either plain sights or telescope, and be mounted on tripod or jacob staff. The simpler forms are preferred for forest work. Not unfrequently the engineer's transit is employed, but using the needle. When local attraction is found to exist to such an extent as to destroy confidence in the needle, or when obstacles are very great, the transit should always be used. In this case, the preliminary line should be run by backsights and deflections. The survey then partakes of the nature of a location, and should be conducted with similar care and fidelity.

33. The engineer's chain which was formerly in general use, is 100 feet long and composed of one hundred links. It has largely been superceded by the steel tape, although it is occasionally made use of. The word " chain " is a convenient term, meaning 100 feet, and is commonly used. A set of marking pins will be found of service for temporary stations in running an offset line to some object of importance, or as markers in chaining on a hillside too steep for a whole chain. One or more plumb bobs, each having several yards of small cord wound on a carpenter's spool, should be provided.

34. The axes should be of best quality, with hand-mad *handles,* and not too heavy. The axe of the stakeman sho have a fine edge for dressing and a broad head for dri the stakes. When the stakes are not required to be over feet long, a stout *basket*, having a square, flat bottom, 26 inches, should be furnished the stakeman. He will then pare a basketful of stakes, ready marked, and place them the basket regularly, in the reverse order of their numbers, so that they will come to hand as wanted. *A small hand-sa* no larger than the basket, with rather coarse teeth, wide set, will be found extremely useful in cutting stakes with square heads and of uniform length, and much more rapidly than can be done with an axe. When not in use, it is to be strapped to the inside of the basket, to prevent its being lost by the way. When the basket is about empty, the stakeman, with the assistance of the axemen, can soon replenish it, and the stakes being all numbered at once, there is less danger of a mistake being made in the tally than when they are marked only as wanted.

35. **The level** should be the regular engineer's level, the same as used on location.

36. **The rod** should be self-reading, *i.e.*, to be read by the leveler, as too much time would be consumed in the constant adjustment of a target by the rodman. It should be as long as can be conveniently handled in order to reduce the number of turning points on hill sides. A very convenient rod may be made of thoroughly seasoned clear white pine, 16 feet long and 2 inches wide, with a thickness of 1 inch at the bottom, increasing to one and a quarter inches at 6 feet from the bottom, and then gradually diminishing to three eighths of an inch at the top. The rod is shod with a stout strap of steel, extending 5 inches up the edges, and secured by screws. The top is protected for a few inches by a plate of sheet brass on the back. The face of the rod is a plain surface throughout, and is graduated from the lower edge of the steel shoe as zero. The divisions are fine cuts made with the point of a knife. At the foot and half-foot points the cuts extend across the face. For the tenths and half tenths they extend three quarters of an inch from the right-hand edge, terminating in a line scribed parallel to the edge of the rod, thus forming rectangular blocks half a tenth wide, every other one of which is painted black, the body of the rod being white. The feet are indicated by numeral

painted red on the blank part of the face, each figure standing exactly on its foot mark, and being exactly one tenth high. For the figure 5 the Roman V is substituted and for 9 the Roman IX, so that in case a dumpy level is used the 5 may not be mistaken for a 3, nor the 9 for a 6. At the half-foot points a red diamond is painted, so that the graduated line bisects it. No other figures nor graduations are required. With this rod the leveler can read quite accurately to hundredths of a foot, and after some practice can estimate the half hundredths.

37. The horizontal rod for cross-levels may be made of white pine, 10 feet long and 1 inch thick by 3 wide, tipped with brass, painted white, and graduated to feet and tenths. It must be a straight edge, and is leveled by a pocket level placed upon it when needed, or by a small level embedded permanently in one edge. The vertical rod to be used with it is made of pine 8 feet long and one and a quarter inches square, and graduated to feet, tenths, and half tenths. All rods when not in use should be laid on a flat surface to prevent their being sprung. Leaning them in a corner soon ruins them for use.

38. The clinometer is any small instrument which will measure the slope angle of the surface. The angle is always estimated from the horizon, a vertical being 90°. The rise per 100 feet is found by multiplying the nat. tangent of the slope angle by 100. It may often be found more easily by the leveler reading the rod at a station and then 100 feet left or right of the line. If surface measures are taken in connection with a slope angle they are reduced to horizontal measures by multiplying them by the cosine of the slope angle.

39. The plane-table is rarely if ever used on prelimininary surveys in the United States. Occasional bearings taken to prominent objects by the transit man, or the use of a prismatic compass by the topographer in connection with his sketches, is found to answer every purpose.

40. In a survey made with transit deflections, it is necessary to add a back flagman to the party, who will hold his flag or rod on the point last occupied by the transit, so that the transitman may take a backsight upon it. The direction of a new course in each case is determined by th deflection angle to the right or left of the preceding cou produced. The bearing of one long course near the beginning of the survey having been carefully ascertained, the bearing of each succeeding course is calculated from the deflections, and entered in a column of the field book headed *Calculated Bearings*, from which the line is afterwards plotted. The magnetic bearing of each course should also be taken from the needle, and recorded as such, but is used only as a check on the transit work. The deflections should be made in degrees, halves, or quarters, if possible, to facilitate the calculation of the bearings, and to admit of using a traverse table.

41. The attached level and vertical arc of the transit are useful in determining approximately the grade of the line run in advance of the level party, or in seeking for one assumed grade to which it is desired that the line shall conform. For this purpose it is only necessary to set the vertical arc to the angle corresponding to the grade as given in Table XIV, and let the head chainman move about until a point on his rod at the same height from the ground as the telescope is covered by the horizontal cross-hair.

42. The point on the ground where a transit is set up is marked by a good-sized plug, flat headed, and driven down flush with the ground, with a tack set in the head to show the exact point or center. This is called a *transit point.* When a transit point occurs at a regular station, the stake bearing the number of that station is set 3 feet to the left of the line opposite the plug and facing it. When a transit point occurs between stations the stake is driven 3 feet to the left of it, marked with the number of the preceding station + the distance from that station in feet.

43. As a transit is capable of giving a line with great precision, it is important that the flags used in connection with it should be equally precise in giving points. An excellent flag for this purpose is made of well-seasoned clear white pine 10 feet long, two and a half inches wide, and 1 inch thick. It is tapered for the last 4 inches to an edge at one end, the edge being formed at the middle of the width. The tapered end is shod with a band of steel covering the edge of the rod, and secured by screws, and the steel is brought to a sharp edge at the point of the rod. The rod is then painted white and tipped with brass at the square or upper end. A center line on the face is then struck from the point of the steel to the middle of the brass tip by means of a piece of sewing silk, and a fine cut made with a knife and steel straight edge. The center line must *not* be scribed parallel to one edge of the rod, as this is rarely ever straight. The face of the rod is then divided into 1-foot spaces, measured from the head of the rod, and these are painted red on either side of the center line in alternate blocks. On the back of the rod at three and a half feet from the point is placed a small ground-glass bubble-tube, mounted very simply, and attached to the rod by a brass plate and screws, and guarded by two blocks of wood for protection. The center line of the rod is made vertical by a plumb-line while the level tube is being attached, which ever after secures a vertical rod. If only 2 feet of this rod can be seen over any obstruction, a point can be set with great precision, provided the level tube is in adjustment. This flag can also be used as a plumb in chaining with much more satisfaction than a cord and weight, especially in windy weather.

44. A transit survey usually requires more clearing than one made by compass. When a given course is to be produced in a forest, some large trees will inevitably be encountered, but the labor and delay of felling them may be avoided by the use of *auxiliary lines.* These may be classified as running *parallel* to the main line, at a *small angle* with it, or at a *large angle* with it.

45. The parallel line is established by means of two short perpendicular offsets measured with care before reaching the obstacle, and the main line is established beyond the obstacle by means of two more equal offsets. But since short backsights are to be avoided, these offsets should be at least 100 feet apart, and it may be difficult to find a parallel line of sufficient length which does not strike some other obstacle, or at least require considerable extra clearing.

46. The auxiliary lines making a small angle with the main line are more convenient, not only on this account, but because they require a less number of transit points. By them an isosceles triangle is formed on the ground, having the intercepted portion of the main line as base, and the vertex *near* the obstacle. The deflections at the points wher *the lines* leave and join the main line are similar and eq and the deflection at the vertex is double in amount and opposite in direction. No calculation is necessary, for the error in measurement due to the deviation is too small to be noticed, and since the main line is immediately resumed, the calculated bearings of the auxiliary lines are unnecessary. Should the point where the second line joins the main line prove unsuitable for a transit point, the second line may be produced to any convenient point beyond, and so go to form an isosceles triangle on the opposite side of the main line, the triangle being completed by running a third line parallel to the first, and equal to the difference of the first and second. Again, the second line may encounter a serious obstacle before reaching the main line. To avoid this a parallel to the main line may be run from the end of the first line for a convenient distance, and there the second line be put in parallel and equal to its first position, as before described, thus forming a trapezoid.

47. The following **general solution** of this problem allows the engineer to make use of any number of auxiliary lines, provided that none of them make an angle of much more than one degree with the main line, with a certainty of resuming the main line in position and direction at the extremity of any course desired, and without necessitating any trigonometrical calculation. It is based on the assumption, practically true for small angles, that the sines are proportional to their angles, and is expressed by the following **rule:**

Call all deflections to the right *plus*, all to the left *minus;* multiply the length of each course in feet by the algebraic sum *in minutes* of all the auxiliary deflections made to reach that course; take the algebraic sum of these products, and when the sum equals zero the extremity of the last course will be on the main line. The deflection required at that point to give the *direction* of the main line is equal to the algebraic sum of all the preceding deflections, but taken with the contrary sign.

Thus, if we have left the main line at *A*, and run by these notes: (Fig. 1.)

Sta.	Defl.	Dist.		Factors.	Products.	
A	16′ R	190	we shall have these products:	$+16 \times 190 =$	$+3040$	
B	31′ L	120		$-15 \times 120 =$		-1800
C	18′ R	175		$+\ 3 \times 175 =$	$+\ 525$	
D	13′ L	265		$-10 \times 265 =$		-2650
E	15′ R			$+\ 5 \times (?)$		
					3565	-4450
and their algebraic sum is						$-\ 885$

Therefore to render the sum zero we must add 885 as the product of the last course. But 5′ is already given as one factor, so that the other factor must be $\frac{885}{5} = 177$, which is the length of the last course, giving some point *F* on the main line. The deflection at *F* from the last course to give the direction of the main line is

$$16 - 31 + 18 - 13 + 15 = 5'$$

and changing the sign we have $-5'$; that is the deflection is to the *left*.

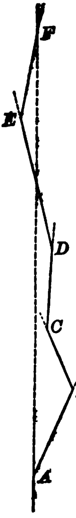

Fig. 1.

The distance on the main line from *A* to *F* equals the sum of the courses, or 927 feet, but this we have by the stations, which have been kept by stakes in the ordinary way. All the stakes on the auxiliary lines will be more or less off the main line, but as these offsets are usually very small, they are considered of no consequence on a preliminary survey through a forest. In Fig. 1 the offsets are very much magnified. **The field notes** of such auxiliary courses should be kept, not as regular notes, but on the margin or opposite page, and in such a way that, while the line may be retraced by them on the ground, the draughtsman may see that it is not necessary to plot them, when a straight line ruled and measured through is sufficient. It is obvious that in selecting a closing course either the deflection may be assumed and the length calculated, or *vice versa*, but care should be taken to assume such values as do not involve a fraction in either factor, if possible.

48. ***The method of passing an obstacle on the line***

auxiliary lines at a large angle with the main line will be resorted to only when circumstances are such that the other methods mentioned cannot be employed, as in passing a building, pond, or densely wooded swamp. In such a case we may turn a right angle with the transit, and measure accurately one offset, putting a transit point at its extremity, where another right angle will give a parallel line. If the offset prove too short for an accurate backsight, a temporary point at a sufficient distance may be established for that purpose on the offset line produced before the instrument is removed from the main line. If any other angle than 90° is used it should be selected, when circumstances permit, so that the distances on the intercepted part of the main line may be in some **simple ratio** to the distances measured on the auxiliary line. Thus a deflection of 60° gives a distance on the main line equal to half the length of the auxiliary course, that is,

60°	gives a ratio of $\frac{1}{2}$	=	0.5	
53° 08′	"	"	"	0.6 nearly
45° 34½′	"	"	"	0.7
36° 52′	"	"	"	0.8
25° 50½′	"	"	"	0.9

the angles being taken to the nearest half minute.

49. If it be desired that the stakes on the auxiliary line should stand on **perpendiculars** through the true stations on the main line, a certain correction must be added to each chain length depending on the angle which the auxiliary makes with the main line. If there is a fraction of the chain at either end of the course, a proportional addition must be made for this. Thus, by referring to the table of external secants, we find that we must add a correction as follows:

2° 33½′...0.1 ft. per chain		6° 45½′...0.7 ft. per chain.	
3° 37′ ...0.2 "	"	7° 13½′...0.8 "	"
4° 26′ ...0.3 "	"	7° 39½′...0.9 "	"
5° 07′ ...0.4 "	"	8° 04′ ...1.0 "	"
5° 43′ ...0.5 "	"	9° 52′ ...1.5 "	"
6° 15½′...0.6 "	"	11° 22′ ...2.0 "	"

These methods of suiting the angle to an even measure are much superior to assuming an even number of degrees deflection, and then calculating the distance by trigonometry. The last table, which may be extended indefinitely by reference to the table of Ex. secants, is perfectly adapted to **chaining** by surface measure **on regular slopes** when the slope angle is known, the chain being lengthened by the correction corresponding to the slope angle.

50. If the chain is lengthened as per above table on auxiliary lines, the numbering of the stakes goes on as usual, but they should have an additional mark as × to show that they are off the main line; and they may stand facing the true stations which they represent, and the length of offset, if known, may also be recorded on them. The leveler will then understand that he is to read the rod not only at the stakes as they stand, but also at the true stations, as nearly as may be. The transit man will always make **a diagram** in his field book, showing exactly the method pursued in reference to auxiliary lines. Having passed the obstacle, it is advisable to return to the main line by a course equal in length to the first auxiliary, and making an equal angle with the main line. If this cannot be done from the end of the first course, a parallel to the main line may be run any convenient distance, and the return line then put in, forming a trapezoid.

51. When there is no **obstruction** to sight on the main line, but only **to measurement,** a transit point should be set in line beyond the obstacle before the transit leaves the main line, as a check on the other operations, and the main line should be afterward produced from this point by backsight on the main line, rather than by deflection from an auxiliary line.

52. The main line should always be resumed as soon as practicable, making the auxiliary lines the mere exception. When a number of courses at a large angle are likely to be required before the main line can again be reached, it may be better to consider these as regular courses of the survey, and to note them as such. The *simplest* method is always the *best,* because least likely to involve mistakes.

53. When the **natural obstacles** are so **numerous** and of such magnitude as to render any continuous line of su vey or *location* extremely difficult, if not impossible, as in case of a bold rocky shore, all the data necessary to a location should be gathered with precision on the preliminary survey, the measurements and angles being taken with the greatest care, and as many checks as possible should be introduced to verify the work. In meandering such a shore it is probable that a large number of short courses will be used which may be measured correctly, but there is liability to error in the angles. To verify the latter the more conspicuous transit stations on the prominent points of the shore are selected, and these being named by the letters of the alphabet, the deflections between them are taken by careful observations repeated a number of times, as for a triangulation. These points, joined by tie-lines, then form a survey of themselves, much simpler than the full traverse. To obtain the length of these tie-lines, the angles between them and the courses meeting at the same station are measured. Then since each tie-line forms the closing side of a field, in which all the bearings are known, and all the distances, save one, that one may be calculated by latitude and departures. But the angles should first be tested for error in each complete field, and if the error be large the angles must all be remeasured until the error is found and corrected, but if very small it may be distributed among the angles, or among those most probably inaccurate. Before calculating the traverse of any of these fields, it will be advantageous to assume, for an artificial meridian, a line parallel to the average direction of the shore for several miles, and to refer all courses to this meridian for their bearing. This meridian is called the *axis* of the survey, and all bearings referred to it are called *axial bearings*, as distinguished from magnetic bearings. The magnetic bearing of the axis should be some exact number of degrees, so as to facilitate the reduction from one system to the other.

54. In plotting the map, the axis is first laid down, and then the lettered stations in their respective positions, after which the meandering surveys can be filled in. The map being drawn on a scale of 100 feet to an inch, and the contours constructed from the notes of the level and cross-level parties, the engineer may project the location upon it with great certainty and economy of result. But he should calculate the traverse of the location as projected, and compare it with the traverse of the preliminary, to eliminate all errors in drafting, before taking his notes to the field to reproduce the location on the ground. Any point where the location crosses the preliminary should have the same latitude and longitude by the traverse of either line. This system, though laborious, is the only one that will ensure a successful location under the circumstances supposed. Advantage may sometimes be taken of cold weather to cross bays and inlets on the ice, but there is great liability to error in angles taken upon the ice, due both to its motion and to the sinking of the feet of the tripod into the ice as soon as exposed to the rays of the sun.

CHAPTER III

THEORY OF MAXIMUM ECONOMY IN GRADES AND CURVES

55. Choice of Routes. Before commencing the field work of location it devolves upon the engineer to decide as to which of the surveyed routes shall be adopted as being most advantageous in all respects, and also to establish the maximum grade in each direction and the minimum radius of curve on that route.

The general considerations which guide the engineer in the selection of one of several routes for location are such as were hinted at in the chapter on reconnaissance, but upon the completion of the preliminary surveys he has at hand a large amount of information which enables him to consider this important question much more in detail. Unless his instructions are explicitly to the contrary, he may assume it to be his duty to find the *best line*, or that one which, for a series of years following the completion of the road, will require the least annual expense, including interest on first cost. The finances of the company may be so limited as not to permit the construction of the best line at once, and it may then be the duty of the engineer to select the *cheapest line*, or that of least first cost, as a temporary expedient, with the expectation of building the road at its best when the improved credit of the company will permit. But generally he will be able to build the cheaper portions of the best line at once, only making deviations and introducing heavier grades at the expensive points to avoid a cost beyond the present means at his command. The selection of the best line may be a question as between different routes or as between different grades and curves on the same route. We will consider the latter case first.

56. To solve the **problem of true economy** we must determine the actual expense both of building and operating the line at a given maximum grade, and also what changes will be made in these expenses by a change in that maximum. We have then, on one hand, the annual interest upon the original cost, and, on the other, the annual expense of operating the road. *The best grade is that which will render the sum of these two a minimum.* Both forms of expense consist of two parts: one that is affected by a change in grade, and the other that is not. Clearly the former is the only one we have to consider in either, since when the sum of the variable portions is a minimum, the sum total will be a minimum also. The varying portions then are functions of the grade, though independent of each other. If, therefore, we let z' represent the maximum grade in feet per mile, and let x represent the corresponding value of that portion of the annual expense which varies with the grade, and establish the relation existing between the two, we shall have $x = f\ (z')$. Similarly if we let y represent the interest on so much of the first cost as is affected by grade, we shall have $y = f'\ (z')$. The problem then is to find that value of z' which shall render

$$x + y = a\ minimum.$$

Let us now seek the complete expression represented by $x = f\ (z')$.

The elements that enter into this expression are numerous, and will be considered in succession.

57. The tractive force of a locomotive is limited by the friction existing between the driving wheels and rails, since a locomotive is designed to have its boiler and cylinder capacity somewhat in excess. This friction, called the adhesion, is expressed as a percentage of the weight on the driving wheels, and under ordinary working conditions is found to be from 20 to 25 per cent of the weight. The weight imposed by the driving wheels is limited by the ability of the rail material to withstand abrasion and deformation; with iron rails the limit per pair of drivers is fixed at 24,000 pounds, with steel rails at 48,000 pounds. There are instances of 52,000 pounds permitted.

58. The expense of running an engine one mile, *hauling a train* on the proposed road, can be estimated only fro *the experience* on other roads similarly situated. The ite of expense while the train is on the road are fuel, the wages of the engineer and the train crew, together with many smaller items of transportation.

As previously stated, when lines of different *length* are to be compared for expense per train mile, it is only those items affected by grade which concern us in this problem.

The cost of a train mile has been increasing for some years past. An average figure may be $1.50, and the part affected by the ruling grade is about 52 per cent of this amount.

Where the bulk of traffic warrants their use, heavy locomotives give more economical results than lighter ones.

59. The resistance offered to the motion of a railway train is occasioned by a variety of causes, concerning which a great deal of uncertainty exists as to their relative effect. An investigation which should seek to determine the exact amount of each partial resistance, and then by a summation derive the total, would be tedious, and, in the present state of our knowledge, unsatisfactory. We shall therefore simply group the resistances under three general heads, namely:

Resistance due to uniform motion on a straight, level track;

Resistance due to grade;

Resistance due to curvature.

60. The first of these, considered as an aggregate of the various items of friction in locomotive and train, of oscillations and impacts, and of resistance of the atmosphere, is found to vary nearly or quite as the square of the velocity. The friction of a locomotive is greater in proportion to its weight than that of a car, owing to its many moving parts, so that the resistance of a short train is greater in proportion to its total weight than that of a long train. The resistance of the atmosphere is greater also in proportion to the weight of a short train than of a long one. An empty train will offer more resistance in proportion to its weight than a loaded one. A formula which shall express the resistance of a train to uniform motion must include at least the velocity and the weight of the train and locomotive.

The following empirical formula was given in the former editions of this book. It is based upon the records of a large number of experiments and is designed to give the resistance *per ton for all trains,* whether freight or passenger, and at any velocity, under ordinary circumstances. Accidental circumstances, such as the state of the weather, and the condition of the road-bed, rails, and rolling stock, may largely modify the resistance, but these, of course, are not taken into account in the formula.

$$q = 4.82 + \left(.0053 + \frac{.000478E^2}{E + W + T}\right) V^2 \qquad (1)$$

where $V =$ the velocity of the train in miles per hour, $E =$ the weight of the engine and tender in tons, $W =$ the weight of cars in tons, $T =$ the weight of freight in tons, and $q =$ the resistance to uniform motion in pounds per ton. The short ton of 2000 pounds is the one used.

An elaborate series of experiments * on train resistance has been conducted by Prof. E. C. Schmidt of the University of Illinois. The tests covered a wide range of velocities, weights, and loadings of trains. Formulas were developed for several different loadings. The following single empirical formula expresses the value of the train resistance in pounds per ton:

$$q = \frac{V + 39.6 - 0.031w}{4.08 + 0.152w} \qquad (2)$$

where $w =$ the average weight of car and load in tons, and V and q are as in eq. (1).

61. The second resistance considered is that due to gravity in grades. It varies in the exact ratio of the rise to the length of the grade.

Let G_s = rise of grade in feet per station;
G_m = rise of grade in feet per mile;
q' = resistance in pounds per ton due to grade.

Then,

$$\left.\begin{aligned} q' &= 2000\frac{G_s}{100} = 20G_s \\ \text{and} \quad q' &= 2000\frac{G_m}{5280} = \frac{1}{2.64}G_m \end{aligned}\right\} \qquad (3)$$

The first of these equations expressed in words is easily remembered. *The grade resistance is equivalent to* 20 *pounds per ton per rate of grade per station.*

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* See Bulletins 43 and 59 of the Engineering Experiment Station of the *University* of Illinois; also Journal of the American Society *Mechanical Engineers* for May and September, 1910.

62. The third resistance considered is that due to curvature of the track. This resistance is due to the friction of the wheels upon the top of the rail, and of their flanges upon the side of the rail. The top friction is lateral, due to the oblique position of the wheel on the rail, and longitudinal, due to the greater length of the outer rail, since both wheels are rigidly attached to the axle. The flange friction is due to the reaction of the top friction, which, combined with the parallelism of the axles, throws the truck into an oblique position on the track. A forward flange presses the outer rail, while a rear flange is usually in contact with the inner rail. The centrifugal force of the car will increase the pressure on the outer rail, unless the ties are inclined at an angle sufficient to counterbalance this force. But if the ties are inclined too much, or the velocity is less, the pressure on the inner rail will be increased. An uneven track will cause the truck to pursue a zigzag course, increasing the resistance considerably.

The curve resistance probably varies from about ½ pound to 1 pound per ton on a 1° curve. For sharper curves it varies as the degree of curve. The value depends on the character of the rolling stock, the location of the curve with respect to grade, and on the speed of the train.

63. Curve Compensation. When a ruling grade is lessened for curvature, it is said to be *compensated for curvature*, or merely *compensated*, and the equivalent grade resistance per degree of curve is called the *rate of compensation*.

To ascertain the relation between the curve and the grade resistance, the following reasoning may be employed:

Assuming the *rate of compensation* as 0.035 and that the curve resistance varies directly as the degree of curve, we have

$$\left.\begin{aligned} 0.035D &= G_s \\ \text{and}\qquad 1.847D &= G_m \end{aligned}\right\} \tag{4}$$

For definition of degree of curve, see § 84.

Then if q'' = the curve resistance in pounds per ton on any curve, by combining first eqs. (3) and (4) and substituting q'' for q' there results

$$q'' = 0.70D$$

The coefficient of D in eq. (4) is adopted as an average of values suggested in the recommendations quoted below.

Compare also the latter part of § 62.

Example. If the ruling grade of a road is 1 per cent, what is the allowable grade on a 4° curve?

From first eq. (4) the additional resistance caused by the 4° curve is equivalent to 0.14 of a foot per station. Consequently the 1.0 per cent grade must be lowered to 0.86 per cent.

The American Railway Engineering Association has made the following recommendations for the rate of compensation:

(*a*) Compensate 0.03 per degree:

When the length of curve is less than half the length of the longest train.

When a curve occurs within the first 20 feet of rise on a grade.

When curvature is in no sense limiting.

(*b*) Compensate 0.035 per degree:

When curves are between one half and three quarters as long as the longest train.

When the curve occurs between 20 and 40 feet of rise from the bottom of the grade.

(*c*) Compensate 0.04 per degree:

Where the curve is habitually operated at low speed.

Where the length of the curve is longer than three quarters of the length of the longest train.

Where elevation is excessive for freight trains.

At all places where curvature is likely to be limiting.

(*d*) Compensate 0.05 per degree wherever the loss of elevation can be spared.

64. Maximum Trains. It is evident that grades and curves, by their resistances, fix a limit to the weight of a train which a given engine can haul over them.

To find an expression for the maximum train which a given locomotive can haul over a given compensated grade:

Let P = the draw-bar pull of the locomotive in pounds;
T' = weight of paying load in tons per maximum train;
W' = weight in tons of cars carrying the load T'.

Then for uniform motion at a given velocity,

$$(W' + T')(q + q') = P$$

Let t = the average load of one car in tons, and w = the average weight of one car including load in tons. The number of cars, n, all assumed loaded to the average, will then be $\frac{T'}{t}$.

Then $W' + T' = nw = \frac{wT'}{t}$, and substituting in eq. (6) we derive

$$T' = \frac{t}{w}\left(\frac{P}{q + q'}\right) \tag{7}$$

In this equation q = the resistance per ton due to uniform motion, q' = the resistance per ton due to the *maximum grade* opposed to the direction of the train.

For accelerated motion the reaction of inertia of the train must be added to the above resistances. This is estimated at $\frac{1}{2}q$, in order that a train starting from the rest may acquire the requisite maximum velocity, even on a maximum grade, in a reasonable time, say from three to six minutes. Therefore, for accelerated motion,

$$T' = \frac{t}{w}\left(\frac{P}{\frac{3}{2}q + q'}\right) \tag{8}$$

The value of q in eq. (2) may be substituted in eq. (8) and we obtain

$$T' = \frac{t}{w}\left(\frac{P}{\frac{3}{2}\left(\frac{V + 39.6 - 0.031w}{4.08 + 0.152w}\right) + q'}\right) \tag{9}$$

Also, for the weight of maximum train and load

$$W' + T' = \left(\frac{P}{\frac{3}{2}\left(\frac{V + 39.6 - 0.031w}{4.08 + 0.152w}\right) + q'}\right) \tag{10}$$

which is the expression required.

When there is no grade, q' becomes zero, hence for a level track eqs. (8) and (9) become

$$T'_0 = \frac{t}{w}\,\frac{2P}{3q} \tag{8a}$$

$$T'_0 = \frac{t}{w}\,\frac{P}{\frac{3}{2}\left(\frac{V + 39.6 - 0.031w}{4.08 + 0.152w}\right)} \tag{9a}$$

where T'_0 = the weight of paying load in tons per maximum train on a level grade.

65. An engine-stage is a division of the road to which a locomotive is limited, and over which it regularly hauls a train. Its length varies, on existing roads, from 50 to 200 miles or more, depending on the grades, on the length of the whole line, and on the distance between points favorable for the location of shops, etc. The average engine-stage on American roads is not far from 100 miles. If there are to be several engine-stages on the proposed line, the problem of maximum economy of grade must be solved with reference to each of them separately.

Let L = length of engine-stage in miles;

e = that part of expense per train mile which varies with grade (in dollars);

A = average annual paying freight in tons moving in one direction, and

a = average annual paying freight in tons, moving in the opposite direction; and if these are not equal, let A be greater than a. Now T', eq. (9), is the maximum train-load which, at a velocity V, should be hauled up steepest grade z', opposed to the direction of the tonnage A; hence $\frac{A}{T'}$ = the number of trains per annum; and since each train must go and return, $\therefore \frac{2LA}{T'}$ = the total train-mileage per annum.

If there were no return tonnage, the annual expense chargeable to A would be $\frac{2ALe}{T'}$, but since some of the cars return loaded with the freight a, these are not chargeable to A, and must be deducted from the above expression. Hence if we denote the annual expense of engine-mileage by x,

$$x = \frac{(2A - a)Le}{T'} \tag{11}$$

in which the value of the maximum grade z' is involved in the value of T'.

But we may obtain an expression for x in terms of z'; for, at any given velocity, the resistance, q_0, on a level is equal to the resistance due to a certain grade z_0, the value of which is, by eq. (3), for uniform motion,

$$z_0 = 2.64q_0$$

So the resistance, q, to motion up a grade z' is equal to the resistance due to some grade $z = 2.64q$, the total resistance being that due to the combined grades $z + z'$. Now, since the gross weight of a maximum train, under a constant engine power, is inversely as the resistances, we have, for conditions of accelerated motion:

$$\frac{w}{t}T' : \frac{w}{t}T_0' :: \frac{3}{2}z_0 : \frac{3}{2}z + z'$$

whence

$$T' = \frac{T_0' z_0}{z + \frac{2}{3}z'} \tag{12}$$

in which T_0' = maximum train load on a level line. Substituting this value of T' in eq. (11) we have

$$x = \frac{z + \frac{2}{3}z'}{T_0' z_0}(2A - a)Le \tag{13}$$

which is the complete expression for $x = f(z')$ required.

66. Graphical Solution. Could we also find a complete expression for $y = f'(z')$, we might then proceed to find, by analysis, that value of z' which would render $x + y$ = a minimum. But the value of y cannot be formulated, since it depends on the accidental features of the country through which the line passes; it can only be determined for any given value of z' by an estimate based on the survey. We therefore resort to a graphical solution.

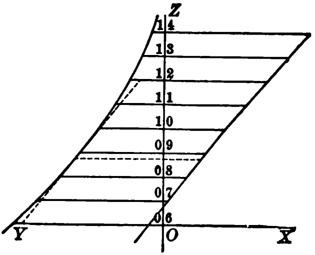

FIG. 2.

Eq. (13) is the equation of a curve in the plane ZX, Fig. 2. If we assume several values of z', and calculate the corresponding values of x, we may lay these off by scale on the axes of Z and X respectively, and so obtain several points through which the curve of annual expense may be drawn. We then make estimates of the cost of constructing the road *at the same* values of z', and taking the annual interest of *ch estimate as* an ordinate y to OZ in the plane ZY, we lay it off to scale at the proper height, thus obtaining a series of points in the plane ZY, through which the curve of annual interest on first cost may be drawn. If now we suppose the plane ZY to be revolved to the left about the axis OZ until it coincides with the plane OX, as in Fig. 2, we shall see that the two curves are convex to OZ and to each other. The shortest horizontal line intercepted by them indicates the minimum value of $(x + y)$, and the point where this line cuts the axis OZ indicates the corresponding value of z', which is the one required. If tangents be drawn to the curves at the points where the shortest horizontal line intersects them, the tangents will be parallel to each other. Any convenient scales may be used to lay off the values of z' and x, provided that the values of x and y be laid off to the *same scale*. It is well to reduce all the values of x by an amount common to them all, and the same with respect to values of y, before laying them off to scale. This will bring the two curves nearer together without altering their form.

67. To facilitate the calculation of x, a table might be computed giving values of $\frac{1}{T'}$ for several locomotives and based on eq. (9).

The value of x can be found by multiplying the reciprocal of T' by $(2A - a)Le$.

The data for a single locomotive and train will be taken as follows:

$t = 30$ tons of freight per car load;
$w = 45$ tons per car and load;
$V = 12$ miles;
$P = 20{,}000$ pounds.

Substituting these values in eq. (9) and assuming different rates of grade, we can find the maximum loads of freight which the locomotive can haul up these grades. Further data and a complete solution of the problem are given in § 69.

68. In the given solution, the grades have been compensated. Grades less than the ruling grade need not necessarily be reduced for the curves upon them, unless the sum of the grade and the curve-equivalent exceeds the ruling grade.

69. For an *example*, let us suppose that a certain engine-stage is to be 100 miles long, and that an estimate of the cost of construction has been made, based on a ruling grade of 52.8 feet per mile against the heavier traffic, and that the annual interest on the estimate amounts to $168,000.

Let us further suppose that the average traffic in one direction is estimated at 375,000 tons per annum, and in the other direction at 125,000 tons, and that the part of the train-mile expense due to grade is 80 cents; hence $(2A - a)Le =$ $50,000,000. We are now required to find the most economical ruling grade.

First, select at least two other possible ruling grades, and having made an estimate of the cost of constructing the road upon each, take the annual interest of each, as in the first case.

Let us suppose the two ruling grades thus selected to be 73.92 and 31.68 feet per mile, or 1.4 feet per station and 0.6 feet per station, and the interest on the estimates to be $145,596 and $204,388 respectively. Then the information may be grouped as in the table below.

G_s	y	$\frac{1}{T'}$	x	$x+y$	z'
1.4	145 596	....	....	....	73.92
1.3	149 886				
1.2	155 050	.0023170	115 850	270 900	63.36
1.1	161 088	.0021673	108 385	269 473	58.08
1.0	168 000	.0020175	100 875	268 875	52.80
0.9	175 786	.0018677	93 385	268 171	47.52
0.8	184 446	.0017180	85 900	270 346	42.24
0.7	193 980				
0.6	204 388	....	......	......	31.68

The values of y in the second column are obtained by interpolating by second differences from the interest on costs of construction of the 1.4, 1.0, and 0.6 per cent grades. T' is obtained from eq. (9), using the data in § 67. The fourth column is obtained by multiplying $\frac{1}{T'}$ by $(2A - a)Le$, the numerical value of the latter being $50,000,000. We observe that the values of x and y increase in opposite directions, and that the minimum value of $(x + y)$ will occur on a grade *of about 0.9* per station, therefore this will be the most *nomical grade* for the given conditions. As previously noted, the value of $(x + y)$ will not be the annual outlay of the road, or engine stage, because many items of expense which are independent of the ruling grade are not included in the value of 80 cents per train-mile.

As a general proposition it is advisable to increase the size of locomotives. Certain limitations to increase of size occur, however, such as strength of bridges, the amount of traffic available, and so on.

The problem may be pursued further with other locomotives and loadings, in which case it is to be remembered that as the size of the locomotive increases, the value of e will be changed. Also the velocity may be increased or decreased and if this is done the value of the draw-bar pull will change

70. Pusher Grades. Since x, eq. (11), varies directly as L, it is important that an engine-stage having heavy grades should be short. Its length, however, must be consistent with the economical length of the adjoining engine-stages, and with the amount of work which a locomotive ought to perform daily. The most favorable condition for a road would be that in which all the engine-stages were operated at equal expense. But if, to secure this result, the engine-stage of heavy grades must be unreasonably reduced in length, it will be better to adapt the grades to the use of two locomotives per train.

71. Maximum Return Grades. The maximum grade z', opposed to the heavier tonnage A, having been determined, we have now to consider what is the limit to grades in the opposite direction. The locomotives are supposed to haul their maximum loads in moving the tonnage A, and since the return tonnage, a, is less than A, the locomotives, in returning, will not be worked to their full capacity if they encounter no grades steeper than z'. We therefore have a margin of power in the returning locomotives which may be taken advantage of to cheapen the cost of construction, or to shorten the line, by introducing grades, steeper than z', against the lighter traffic.

The weight of a maximum train moving up the grade z' is, eq. (10), $W' + T'$; the weight of the train returning will be

$$W' + \frac{a}{A}T' = \left(\frac{w - t}{t} + \frac{a}{A}\right)T'$$

Substituting this in place of $(W' + T')$, eq. (10), and solving for q', we find the resistance due to a maximum grade opposed to the returning train. Whence, by eq. (3), if we let $Z =$ the maximum return grade,

$$Z = 2.64\left[\frac{P}{\left(\frac{w-t}{t} + \frac{a}{A}\right)T'}\right] \qquad (14)$$

Inasmuch as the value of Z varies with every change made in z', the engineer, when estimating the cost of construction upon the basis of any maximum grade of z', should take care that the return grade of Z nowhere exceeds its limits as given by the last eq. (14). In the example, § 69, $z' = 52.8$ approx.; hence $T' = 495.6$, eq. (9). Substituting these values in eq. (14), we find that $Z = 127.8$, which is therefore the limit for return grades in this case. These grades should of course, be compensated.

72. Undulating Grades. Suppose that 30 miles per hour is a safe maximum velocity for a freight train going down any grade. Assuming that a train starts down a grade at this velocity, we may find the value of the grade which will cause the train to continue at a constant velocity, without the use of steam or brakes.

Designate the value of G_m in eq. (3) by z, and we have

$$z = 2.64q$$

Substitute the value of q from eq. (2) in this and we get

$$z = 2.64\left(\frac{V + 39.6 - 0.031w}{4.08 + 0.152w}\right) \qquad (15)$$

When $V = 30$ this becomes

$$z = 2.64\left(\frac{30 + 39.6 - 0.031w}{4.08 + 0.152w}\right) \qquad (15a)$$

As a speed of 30 miles an hour is considered unobjectionable, the grade z which induces it cannot be so, provide of course, it does not exceed the values of z' or Z whic were found as the most economical. For the extra wor done by the engine in ascending one grade z is utilized i *descending* the next; and the net result is the same as thoug *the two* were replaced by a uniform grade. The en therefore is not warranted by economic considerations in reducing undulating grades which do not exceed z to a uniform grade, when to do this would cause any increase in the cost of construction, unless z exceeds the grades z' or Z of maximum economy.

73. But when grades exceed z, eq. (15a), the resulting speeds of the maximum train become too great, and the necessary application of the brakes absorbs a portion of the power previously expended in gaining the summit, which is thus worse than wasted, since it increases the wear and tear of machinery and track. Therefore the engineer is justified in spending a certain sum of money in reducing grades which exceed z to that limit. A calculation of the loss of power due to the use of brakes on a grade, and of the cost of that lost power, together with the resulting wear and tear per annum, will give the interest on the sum that may be justifiably spent in reducing the grade from its position of cheapest construction.

74. The limit z is not constant, but depends on the weight of the maximum train, which in turn depends on z'. It will not be the same in both directions unless $A = a$, giving $z' = Z$. In the example § 69, $W' + T' = 743.4$; hence, eq. (15a), $z = 16.24$ descending in the direction of the traffic A. Also $W' + \frac{a}{A} T' = 413.0$, whence $z = 23.04$ descending in the opposite direction. These are the limits in this case at which undulating grades cease to be profitable.

75. Comparison of Routes. We have finally to consider the method for selecting the best line from several proposed routes. For this purpose we determine the most economical grade on each route thought worthy of consideration, and calculate the interest on the *entire cost* of constructing the line with that ruling grade, and also the *annual expense* of operating the line, and take the sum of the two. That route is best in respect to which this *sum* is the least.

76. The value of saving one mile in distance on any route is found by dividing the sum of the annual operating expense and the interest on the cost of construction by the rate of interest, and the quotient by the length of the line in miles.

77. Conclusions. We have now fully discussed t theory and developed the formulas necessary to the mination of the most economical grades; but the vɛ the results in a given case depends upon the correct the engineer's estimates which enter into the formulas. may seldom prove precisely accurate, yet, if he can them within definite limits, he may determine the of maximum economy within corresponding limits. the case of a railroad already finished and in full ope where the elements of first cost, of the existing trafl of the operating expenses are fully known, an investi by means of the foregoing formulas furnishes a critic as to the economy of any proposed alteration of th In several instances which might be named the trun roads have been justified in incurring very heavy e in reducing distances and grades for the cheaper ha of greatly increased traffic.

CHAPTER IV

LOCATION

78. A railroad is said to be located when its center line is established on the ground in the position which it is intended finally to occupy. The location is made by an engineer corps similar in its organization to that employed on preliminary surveys. A fully equipped engineer's transit is required. The other instruments are the same as before except that the target rod may replace the self-reading rod. The magnetic needle is never used upon the center line, except as a rough check on the transit work. It is used, however, to obtain the direction of property lines, roads, and other topographical data.

79. The remarks upon **transit work** in the preceding chapter apply to the running of straight lines on location. All field-work on location should be done with accuracy and fidelity. No guesswork, nor rude approximations, are to be tolerated. All transit points are made as secure and permanent as possible, and the more important ones are guarded by other transit points set in safe positions near by, their distances and directions from the main point being recorded.

The stakes for the stations are made neatly, and somewhat uniform in size, and they are firmly driven. Sometimes a small plug is driven down flush with the surface of the ground to indicate the station point, and the stake is then set near by as a witness.

In locating a very **long tangent** the greatest care is required to make it *straight*. If the tangent is produced from point to point by backsights and foresights, the observation should be repeated in every instance with reversed instrument, to eliminate any possible lack of adjustment, and to check any accidental error. (Indeed it is proper to observe this rule on curves, as well as on tangents.) When some object in the horizon *can* be used as a foresight, it is preferable to set th instrument by this rather than by a backsight. For final location, the line should be cleared to give as continuous a line of sight as possible, but in case of an obstacle which cannot be removed at the time, at least two independent methods of passing it should be employed, so that there may be a check upon the alinement beyond.

80. **The leveler** selects his benches far enough from the line to prevent their being disturbed during the construction of the road. They should be nearly at grade, as a rule, though it is well to leave a bench near a water-course for reference in laying out masonry or trestle-work. The rodman holds the rod at every station, and at every point on the center line where the slope changes direction, so that these points may be accurately defined on the profile. When he uses a target rod, he sets the target as directed by the leveler and after clamping it, takes the reading. He reads to thousandths upon turning points and benches, but only to tenths of a foot elsewhere, and announces the readings to the leveler for record. He also records the readings upon turning points and benches in his own book as a check. At the close of each day the leveler and rodman compare notes, and draw a profile of the line surveyed. (See also §§ 28, 29, 30.)

81. The **fixing** of the **grade-lines** upon the profile is one of the most important operations connected with the location. It is usually performed by the engineer in charge of the locating party, as being most conversant with the general character and detailed requirements of the line. The maximum gradients will have generally been determined in advance from the preliminary data by the principles laid down in the preceding chapter, but the position of each grade-line relative to the profile of the surface must be left to the judgment and skill of the engineer. In general, the grade-line is so placed as to equalize the amounts of excavation and embankment, but there are various exceptions to this rule. Thus, the excavation may be in excess: *first*, when it is necessary to pass under some other road or highway, the grade of which cannot be changed; *second*, when valuable property is to be avoided, the appropriation of which would cost more than the excavation; *third*, when the grade is at the maximum near a summit, and cannot be raised parallel to itself without incurring too great an expense for masonry, etc., at some other part of

the line. The embankment may be in excess, *first*, when the country is flat and wet, in order to keep the road-bed well drained (the grade-line should be at least two feet above the average level of the surface, or above the high-water mark, if the district is subject to overflow); *second*, in approaching a stream, where it is necessary to raise the grade above the requirements of navigation; *third*, when the cuttings on the line are largely in solid rock, and a cheaper material for embankments may be conveniently had at other points; *fourth*, in a district subject to heavy drifts of snow by which deep cuts would be liable to be obstructed; *fifth*, in side-hill work, where there is danger of land-slips; *sixth*, when it is determined to supply the place of a portion of an embankment by a timber trestle-work or other viaduct.

The apparent equality of cut and fill on the profile does not represent an equality in fact, owing to the different bases and slopes of the sections adopted, and to the various inclinations of the natural surface transversely to the line. This is especially true in side-hill work, where there are both cut and fill at every point, while the profile shows very little of either. In the latter case it is an excellent plan to combine with the profile of the center line the **profiles of parallel lines** ten or twenty feet either side of the center, and drawn with different colored inks, as these will indicate tolerably well the relative amount of cut and fill required. But after the grade has been thus chosen, the only safe method in side-hill work is actually to compute the amounts of excavation and embankment from cross-sections, mark the amount for each cut and fill on the profile, and compare the results. Any changes required in the grade or alinement may then be discovered and effected before the work of construction has begun.

CHAPTER V

SIMPLE CURVES

A. Elementary Relations

82. The center line of a located road is composed alternately of straight lines and curves.

The straight lines are called **tangents** because they are laid exactly tangent to the curves. A tangent may be indefinitely long, but should never, as a rule, be shorter than 200 feet between two curves which deflect in opposite directions, nor shorter than 500 feet between curves which deflect in the same direction. A curve should not be less than 200 feet long. When a tangent is said to be *straight*, the meaning simply is that it has no deflections to the right or left; fo since it follows the surface of the ground, it evidently has a many undulations as the ground. But if we conceive a vertical plane to be passed through the line, a horizontal trace o this plane will accurately represent the line; and so, if we conceive a vertical cylinder to be passed through a curve on th surface of the ground, a horizontal trace of that cylinder wil accurately represent the curve, since all distances and angle are measured horizontally, whatever be the irregularities o the surface. In all problems, therefore, relating to this subject, we may consider the ground to be an absolutely leve plain.

83. A Simple curve is a circular arc joining two tangents. It is always considered as limited by the two tangen points, and any part of it beyond these points is called th curve produced. The first tangent point, or the point wher the curve begins, is called the *Point of Curve*, and is indicate by the initials P.C. The point where the curve ends, and th next tangent begins, is called the *Point of Tangent*, and i indicated by the initials P.T. When accessible, these point are always occupied by the transit in the course of the survey plug driven to fix the point is guarded not only by al stake bearing the number of the station, but also by bearing the proper initials, the "degree" of the nd an "R" or "L" to indicate whether the deflection e Right or Left.

A simple curve is designated either by the radius, R, legree of curve, D.

Degree of Curve, D, is an angle at the center, sub- by a chord of 100 feet. It is expressed by the number ees and minutes in that angle, or in the arc of the imited by the chord of 100 feet. Therefore D *equals ber of degrees of arc per station.*

radius R and degree of curve D can be expressed in f each other.

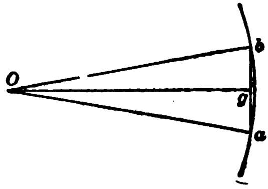

FIG. 3.

b, Fig. 3, be a chord feet subtending an cribed with a radius from the center O. y definition the angle . Bisect the angle a line Og, and this line o bisect the chord ab perpendicular to it; the right-angled triangle bgO we have

$$bg = Ob \times \sin bOg$$

$$\frac{100}{2} = R \sin \tfrac{1}{2}D$$

to find Radius in terms of Degree of Curve:

$$R = \frac{50}{\sin \frac{1}{2}D} \tag{16}$$

find Degree of Curve in terms of Radius:

$$\sin \tfrac{1}{2}D = \frac{50}{R} \tag{17}$$

the practice of English engineers to assume the radius e round number of feet and calculate the degree of which is therefore fractional. In America, on the con- he degree of curve is assumed at some integral number es or minutes, and the radius deduced from this.

Example.—What is the radius of a 3° 20′ curve?

$$\begin{array}{llll}
 & 50 & \log & 1.698970 \\
 & \frac{1}{2}D = 1^\circ\, 40' & \log \sin & 8.463665 \\
\hline
\textit{Ans.} & R = 1719.12 & \log & 3.235305
\end{array}$$

Thus the second and third columns of Table I have calculated, giving at once R or D in terms of the other.

Example.—What is the degree of curve when the rad 600 feet?

$$\begin{array}{llll}
 & 50 & \log & 1.698970 \\
 & R=600 & \log & 2.778151 \\
\hline
 & \frac{1}{2}D = 4^\circ\, 46'\, 48''.73 & \log \sin & 8.920819 \\
\textit{Ans.} & D = 9^\circ\, 33'\, 37''.46 & &
\end{array}$$

Measurement of Curves.

85. A railroad curve is always assumed to be measured a 100-foot tape, and as the tape is stretched straight bet stations it cannot coincide with the arc of the curve, forms a chord to the arc, as in Fig. 3. Consequentl curve as measured from one tangent point to the other inscribed polygon of equal sides, each side being 100 The sum of these sides (with any fraction of a side at e end of the curve) is called the *Length of curve, L.* This le L is evidently a little less than the length of the actua between the same points, but the latter we very seldom occasion to consider.

86. If the chain lengths were taken on the arc instead chords of the curve, the degree of curve would be inve proportional to the radius, and since the arc whose leng equal to radius contains 57.3 degrees nearly, we should

$$D : 57^\circ.3 :: 100 : R$$

or

$$R = \frac{5730}{D}$$

a convenient formula, but only approximately true wh is small, and seriously at fault when D is large; the err *volved being* proportional to the difference in length *10-foot chord,* and the arc which it subtends.

87. The Central Angle of a simple curve is the angle at the center included between the radii which pass through the tangent points (*P.C.*) and (*P.T.*). It is therefore equal to the number of degrees contained in the entire arc of the curve between these points. The central angle will be designated by the Greek letter Δ (delta).

From the definitions of the *length* and *degree* of curve we have the proportion,

$$D : \Delta :: 100 : L$$

Hence, to find the **Length of curve** *in terms of the central angle:*

$$L = 100\frac{\Delta}{D} \qquad (18)$$

Example.—What is the length of a 4^c curve when the central angle is 29°?

$D = 4°$ and $\Delta = 29°$ $\left\{ \begin{array}{l} 4)\underline{2900} \\ \quad 725 \text{ feet} \end{array} \right.$

Ans. $L = 7$ stations+25 feet·

Note.—When Δ or D are not in exact decimals of a degree, reduce both values to minutes before dividing one by the other.

Example.—What is the length of a 4° 20′ curve, when the central angle is 29° 35′?

$D = 260'$ and $\Delta = 1775'$ $\left\{ \begin{array}{l} 260)\underline{177500} \\ \quad 682.69 \text{ feet} \end{array} \right.$

Ans. $L = 6$ stations + 82.69 feet

To find the **Central angle** *in terms of the length and degree of curve:*

$$\Delta = \frac{DL}{100} \qquad (19)$$

Example.—What is the central angle of a 5° curve 730 feet long?

$D = 5°$, $L = 730$, $\frac{5 \times 730}{100} = 36°.5$

Ans. $\Delta = 36° 30'$

To find the **Degree of curve** *in terms of the length and central angle:*

$$D = 100\frac{\Delta}{T} \qquad (20$$

Example.—What is the degree of a curve 8 station and having a central angle of 26° 40′?

$$L = 800, \qquad \Delta = 1600', \qquad 100\frac{1600'}{800} = 200'$$

Ans. $D = 3° \, 20'$

88. If two tangents, joined by a simple curve, are produced (one forward and the other backward) until the intersect, the point of intersection, V (Fig. 4), is called th **vertex,** and the exterior or deflection angle which they mak with each other is equal to the central angle, Δ.

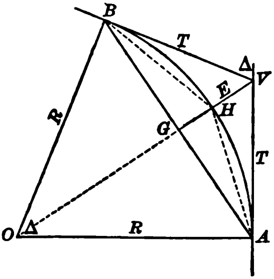

Fig. 4.

The Tangent-distance, T, is the distance from the vertex to either tangent point; thus in Fig. 4, $T = AV = VB$.

The Long Chord, C, is the line AB joining the two tangent points.

The Middle-ordinate, M, is the line GH, joining the middle point of the long chord with the middle point of the curve.

The External distance, E, is the line HV, joining the middle point of the curve with the vertex.

We observe that both the middle-ordinate, M, and the external distance, E, are on the radial line joining the center, O, with the vertex, V, and that this line is perpendicular to the long chord, C, also, that it bisects the central angle $AOB = \Delta$, and its supplement AVB. (Table XLI, 14.)
e also observe that the angle $VAB = VBA = \frac{1}{2}\Delta$ (Table

XLI, 20); and if in the figure we draw the two chords AH and BH, the angle BAH equals one half the angle BOH, or $BAH = ABH = \frac{1}{4}\Delta$ (Table XLI, 18); also the angle $VAH = VBH = \frac{1}{4}\Delta$.

89. If we have laid out two tangents on the ground, intersecting at V, and have measured the angle, Δ, between them, we may then assume any other one of the elements of a simple curve before mentioned, and calculate the rest. If we assume D, for instance, we then find R by eq. (16) or by Table I.

Then having Δ and R, we may proceed to calculate the other elements as they are needed.

90. *To find the* **Tangent-distance** *in terms of the Radius and Central Angle:*

In the right-angled triangle VOA, Fig. 4, we have

$$VA = OA \times \tan VOA$$

$$\therefore \quad T = R \tan \tfrac{1}{2}\Delta \tag{21}$$

Otherwise, approximately: In Table III, opposite the central angle, take the value of T for a 1° curve and divide it by the degree of curve D. If desirable, add the correction taken from Table II, corresponding to D.

Example.—What is the tangent distance of a 4° curve with a central angle of 30°?

$D = 4°$	R (Table I)	log 3.156151
$\Delta = 30°$,	$\frac{1}{2}\Delta = 15°$	log tan 9.428052
Ans. $T = 383.89$ feet		log 2.584203

Otherwise:

By Table III,	4)1535.3
Approximate ans.	383.82
Correction from Table II	.08
Ans. T =	383.90 feet

91. *To find the* **Long Chord** C, in terms of Radius and *Central Angle:*

In the right-angled triangle BOG, Fig. 4, we have

$$BG = BO \times \sin BOG$$

or

$$\tfrac{1}{2}C = R \sin \tfrac{1}{2}\Delta$$

$$\textit{Ans.} \quad C = 2\,R \sin \tfrac{1}{2}\Delta \qquad (22)$$

But in case Δ can be divided by D without a remainder, that is, if the curve contains an exact number of stations (not exceeding 12), we may take the long chord at once from Table IV.

Example.—What is the long chord of a 3° 20′ curve with a central angle of 36° 40′ ?

2	log	0.301030
$D = 3° 20'$, R (Table I)	log	3.235305
$\Delta = 36° 40'$, $\frac{1}{2}\Delta = 18° 20'$	log sin	9.497682
Ans. C = 1081.48 feet	log	3.034017

Otherwise:

$$\frac{\Delta}{D} = \frac{36\frac{2}{3}°}{3\frac{1}{3}°} = 11 \text{ stations}$$

And by Table IV, C = 1081.48.

92. *To find the* **Middle-ordinate** *M, in terms of Radius and Central Angle:*

From Fig. 4

$$M = GH = OH - OG = R - R \cos \tfrac{1}{2}\Delta$$

or

$$M = R(1 - \cos \tfrac{1}{2}\Delta)$$

and since the versine = 1 − cosine

$$M = R \text{ vers } \tfrac{1}{2}\Delta \qquad (23)$$

But in case Δ can be divided by D without a remainder, that is, if the curve contains an exact number of stations (not exceeding 12), we may take the middle-ordinate a once from Table VI.

Example.—What is the middle-ordinate of a 4° 30′ c with a central angle of 40° 30′?

$D = 4° 30'$, R (Table I)	log	3.105022
$\Delta = 40° 30'$, $\frac{1}{2}\Delta = 20° 15'$	log vers	8.791049
Ans. M = 78.717 feet		1.89607

Otherwise:

$$\frac{\Delta}{D} = \frac{40.5}{4.5} = 9 \text{ stations}$$

and by Table VI, $M = 78.717$.

For additional formulas for the middle-ordinate, see Chapter XVII, Track Laying.

93. *To find the* **External Distance** *E in terms of Radius and Central Angle.*

From Fig. 4,

$$E = VH = VO - HO$$

or

$$E = \frac{R}{\cos \frac{1}{2}\Delta} - R = R\left(\frac{1}{\cos \frac{1}{2}\Delta} - 1\right)$$

and since the ex sec = secant − 1 we have,

$$E = R \text{ ex sec } \tfrac{1}{2}\Delta \tag{24}$$

Otherwise, approximately:

In Table III, opposite the central angle, take the value of E for a 1° curve, and divide it by the degree of curve D. If desirable, add the proper correction corresponding to D, taken from Table II.

Example.—What is the external distance E of a 7° 30′ curve when the central angle is 60°?

$D = 7° 30'$,	R (Table I) log	2.883371
$\Delta = 60°$,	$\frac{1}{2}\Delta = 30°$ log ex sec	9.189492
Ans. $E = 118.27$ feet	log	2.072863

Otherwise·

By Table III	7.5)886.38
Approximate ans.	118.184
Correction for $D = 7° 30'$ (Table II)	.084
Ans. $E =$	118.268

94. But, instead of assuming D or R, we may prefer, or may find it necessary to assume, some other element of the curve, the central angle being given.

If we assume the tangent distance, then:

95. *To find the* **Radius** *and* **Degree of Curve** *in terms of the Tangent-distance and Central Angle.*

From eq. (21), and by Table XLII, 40, we have

$$R = T \cot \tfrac{1}{2}\Delta$$

Otherwise, approximately:

Divide the tangent of a 1° curve found opposite the of Δ in Table III, by the assumed tangent-distance; quotient will be the degree of curve in degrees and deci

Example.—The exterior angle at the vertex is 54°, an tangent-distance must be about 700 feet. What shall b degree of curve?

$$\begin{array}{llr} \Delta = 54^\circ, & \tfrac{1}{2}\Delta = 27^\circ \quad \log\cot & 0.292834 \\ & T = 700 & 2.845098 \\ \hline & \log R = & 3.137932 \end{array}$$

Ans. By Table I $D = 4^\circ\ 10' +$

Otherwise:

$$\begin{array}{lr} \text{By Table III,} & 700\underline{)2919.4} \\ Ans.\ D = 4^\circ\ 10'\ 15'' & 4.1706 \end{array}$$

But as it is difficult to lay out a curve when D is fracti we discard the fraction and assume 4° 10′ as the value This may require us to recalculate the value of T, whic do by eq. (21) and find T = 700.8 feet log 2.845596. I other elements are required, they may be calculate eqs. (22), (23), (24), or directly from T and Δ, as follow

96. *To find the* **External distance** *E, in terms o Tangent-distance and Central Angle.*

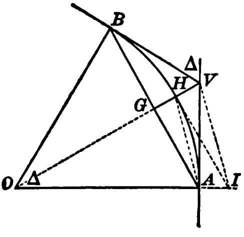

Fig. 5.

In Fig. 5 we have $AOB = \Delta$ and $AV = T$, to $HV = E$. In the diagram the chord AH, and throug draw a tangent line to inte OA produced in I, and join

Then HI is parallel to and since $HI = AV = T$, $AI = HV = E$, VI is parall HA, and $VIH = HAB =$ (Table XLI, 18.)

In the right-angled triangle VHI we have

$$HV = HI \times \tan VIH$$

or

$$E = T \tan \tfrac{1}{2}\Delta \qquad (26)$$

Example.—The angle at the vertex being 54° and the tangent-distance 700.80 feet, how far will the curve pass from the vertex?

$$\begin{array}{lllr}
 & T = 700.80 \text{ (from last example)} & & 2.845596 \\
 & \Delta = 54°,\ \tfrac{1}{2}\Delta = 13°\,30' & \log\tan & 9.380354 \\
\hline
\textit{Ans.} & E = 168.25 \text{ feet} & \log & 2.225950
\end{array}$$

(For the formulas by which to find the long chord and middle-ordinate in terms of the tangent-distance and central angle, see Table XLIII, 12 and 13.)

97. Again, it may be necessary to assume the *external distance* in order to determine the proper degree of curve.

To find the **Radius** *and* **Degree of Curve** *in terms of the External distance and Central Angle:*

By eq. (24)

$$R = \frac{E}{\text{ex sec } \tfrac{1}{2}\Delta} \qquad (27)$$

Otherwise:

In Table III divide the external distance of a 1° curve, opposite the given value of Δ, by the assumed external distance; the quotient is the degree of curve required.

Example.—The angle at the vertex being 24° 30′, the curve is desired to pass at about 65 feet from the vertex. What is the proper degree of curve?

$$\begin{array}{lllr}
 & E = 65 & \log & 1.812913 \\
\Delta = 24°\,30', & \tfrac{1}{2}\Delta = 12°\,15' & \log \text{ ex sec} & 8.367345 \\
\hline
 & \log R = & & 3.445568
\end{array}$$

Ans. By Table I $D = 2°\,03' +$

Otherwise:

$$\begin{array}{lr}
\text{By Table III} & 65)\underline{133.50} \\
\textit{Ans. } D = 2°\,03'\,14'' & 2°.0538
\end{array}$$

We may therefore assume a 2° curve, unless required by the circumstances to be more exact, when we might use a 2° 03′ curve. Assuming a 2° curve, we have by eq. (24)

$$E = 66.75 \quad \log 1.824460$$

Having decided on the degree of curve, we may calculate the remaining elements by eqs. (21), (22), (23), which is always the better way, but we may calculate them directly from E and Δ.

98. *To find the* **Tangent-distance** *in terms of the External distance and Central Angle:*

From eq. (26), and by Table XLII, 40,

$$T = E \cot \tfrac{1}{2}\Delta \tag{28}$$

Example.—The angle at the vertex is 24° 30′, and the curve passes 66.75 feet from the vertex. How far are the tangent points from the vertex?

$E = 66.75$ (from last example)	log	1.824460
$\Delta = 24^\circ 30'$, $\tfrac{1}{2}\Delta = 6^\circ 07' 30''$	log cot	0.969358
Ans. $T = 622.04$ feet		2.793818

99. *Remark.*—Eqs. (27) and (28) are particularly useful in defining the curve of a railroad track where all **original points** are **lost.** Produce the center lines of the tangents of the curve to an intersection V, and there measure the angle Δ. Bisect its supplement AVB, and measure the distance on the bisecting line from V to the center line of the track. This will give $VH = E$. Then R and T may be calculated, and the distance T laid off from V on the tangents, giving the tangent points A and B.

(For the formulas by which to find the long chord and middle-ordinate in terms of E and Δ, see Table XLIII, 26 and 27.)

100. Again, having only the central angle given, we may assume the long chord, or the middle-ordinate, and from either of these and the central angle calculate the remaining elements. Or, finally, the central angle being *unknown*, we may suppose any two of the linear elements given, a from these calculate the rest. As such problems have l practical value, their discussion is omitted. The requi formulas for their solution are given in Table XLIII, and verification of them is suggested as a profitable exer *to the student.*

B. Location of Curves by Deflection Angles

101. In order that the stakes at the extremities of the 100-foot chords, by which the curve is measured, shall be set exactly on the arc of the curve by transit observation, it is necessary at the point of curve, A, to deflect certain definite angles from the tangent AV. Let us suppose that in the curve AB, Fig. 6, the points A, a, b, c, d, etc., indicate the proper positions of the stakes 100 feet apart, and that OA is the radius of the curve. In the diagram join Oa, Ob, etc., and also Aa, ab, bc, etc. Then, by definition, the angle $AOa = D$, and by Geom. (Table XLI, 20 and 11) the angle $VAa = \frac{1}{2}D$. Therefore if we set the transit at A, and deflect from AV the angle $\frac{1}{2}D$, we shall get the direction of the chord Aa, on which by measuring 100 feet from A we fix the stake, a, in its true position on the curve. So again, since the angle aOb, at the center, $= D$, the angle aAb, at the circumference, $= \frac{1}{2}D$. If therefore, with the transit at A, we deflect the angle $\frac{1}{2}D$ from the chord Aa, we shall get the direction of the chord Ab; and when the stake b is on this chord it will also be on the curve, if b is 100 feet distant from a. Thus, in general, we may fix the position of any stake on the curve, by deflecting an angle $\frac{1}{2}D$ from the preceding stake, and at the same time measuring a chain's length from it,—the chain giving the distance, while the instrument at A gives the direction of the point.

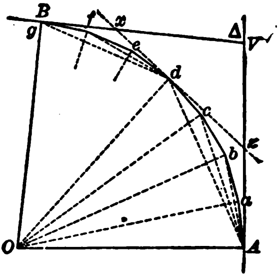

FIG. 6.

$\frac{1}{2}D$ *is called* the deflection-angle of the curve; so that any curve, *the deflection-angle is equal to one half the degree of curve.*

102. Since each additional station on the curve requires an additional deflection-angle, the *proper deflection* to be made at the tangent point *from the tangent* to any stake on the curve is equal to the deflection-angle of the curve multiplied by the number of stations in the curve up to that stake; or it is equal to one half the angle at the center subtended by the included arc of the curve.

103. It may happen that all the stations of a curve are not visible from the tangent point A. When this is the case a new transit-point must be prepared at some point on the curve, by driving a plug and center in the usual manner, and the transit moved up to it. Let us suppose that the point d, Fig. 6, has been selected for a transit-point, and that the transit has been set up over it. Before the curve can be run any farther, it is necessary to find the direction of a tangent to the curve at the point d. The curve beyond d may be located by two different methods.

First Method. Sight at station A with a vernier reading laid off equal to that used in locating the point d, but on the opposite side of zero. Turn the vernier to 0° and the telescope will then point along the auxiliary tangent (line dz). Plunge the telescope and locate the points e, f, etc., by deflecting $(\frac{1}{2}D)$, $2(\frac{1}{2}D)$, and so on. This operation may b
expressed by the following:

Rule. *To find the* **direction of the tangent** *to a cur*
at the extremity of a given chord, deflect from the chord an ang
equal to one half the angle at the center subtended by the chor
(Table XLI, 20.)

The tangent beyond the P.T. may be found by the abo
rule.

104. Second Method. Compute a complete list
deflections as if the entire curve were to be located from
P.C. Locate the point d in the usual way. Set up a
sight at A with a zero reading on the vernier. Turn
telescope outward until the reading which was use
establishing d is reached. The telescope will then be o
auxiliary tangent dz. Plunge the telescope and lay o
deflections for the points e, f, etc., as found in the or
list. Any other transit station than A might have

sighted at provided the *proper deflection were used.* The *general* rule for *this method* is as follows:

Rule for the Second Method of Deflections. When a set up is made at any point on a curve, an auxiliary tangent may be found at that point by sighting at any transit station of the curve with the deflection of the station sighted at laid off on the proper side of zero. Then use the original list of deflections.

Comparison of the Two Methods. The first method must always be used with compound curves, a set up being necessary at each P.C.C. With whole stations and whole degrees of curve neither method has any special advantage. The *particular* advantage of the second method is in the fact that a list of deflections can be *computed* and *checked* before any points on the curve are located, and this list may be used regardless of the number of set ups which are later found necessary.

Caution. Extreme care should be taken that an *incorrect combination* of methods is not made. One method should be chosen and adhered to.

105. The center line is measured, and the stations numbered regularly and continuously through tangents and curves from the starting point to the end of the work. It therefore frequently happens that a curve will neither begin nor end at an even station, but at some intermediate point, or *plus* distance.

If the Point of Curve occurs a certain number of feet beyond a station, the first chord on the curve is composed of the remaining number of feet required to make 100.

Any chord less than 100 feet is called a **subchord.**

If a curve ends with a subchord, the remainder of the 100 feet must be laid off on the tangent from the Point of Tangent to give the position of the next station, so that the stations may everywhere be 100 feet apart.

106. *The deflection to be made for a subchord is equal to one half the arc it subtends.*

Let c = length of any subchord in feet,
d = angle at center subtended by subchord.

Then, from eq. (22), by analogy

$$c = 2R \sin \tfrac{1}{2}d \tag{29}$$

But by eq. (16)

$$2R = \frac{100}{\sin \frac{1}{2}D}$$

$$\therefore \qquad c = 100\frac{\sin \frac{1}{2}d}{\sin \frac{1}{2}D} \qquad (30)$$

$$\therefore \qquad \sin \tfrac{1}{2}d = \frac{c}{100} \sin \tfrac{1}{2}D \qquad (31)$$

When D does not exceed 8° or 10°, we may assume without serious error that the angles are to each other as their sines, and the last two equations become

$$\text{(approx.)} \qquad c = 100\frac{d}{D} \qquad (32)$$

$$\text{and} \qquad \tfrac{1}{2}d = \frac{c}{100}(\tfrac{1}{2}D) \qquad (33)$$

In curves sharper than 10° per station, the error involved in this assumption becomes apparent and must be corrected.

107. If curves were measured on the actual arc, then eqs. (32) and (33) would be true in all cases; but since a curve is measured by 100-foot chords, it is evident that if a 100-foot chord between any two stations were replaced by two or more subchords, these taken together would be longer than 100 feet, since they are not in the same straight line. Let us conceive the actual arc of one station to be divided into 100 equal parts; since the arc is longer than the chord, each part will be slightly longer than 1 foot. Now if we take an arc containing any number of these parts (less than 100), the *nominal* length of the corresponding subchord in feet will *equal* the number of parts, and the deflection for the subchord will be *proportional* to the number of parts which the arc contains. The deflection therefore will be exactly given by eq. (33) if in that equation we let c equal the number of parts in the arc, or the nominal length of the subchord in feet. Having thus obtained the correct value of $(\frac{1}{2}d)$, we may introduce it into eq. (29) or (30), and obtain the *true* value of the subchord, which will always be a little greater than its nominal value.

Suppose, for instance, that the arc of one station is to divided into four equal portions; then each subchord be *nominally* 25 feet long; and by eq. (33)

$$\tfrac{1}{2}d = \frac{25}{100}(\tfrac{1}{2}D) = \tfrac{1}{4}(\tfrac{1}{2}D) \qquad (3$$

which is the correct value of the deflection, whatever be the degree of curve. Substituting this value in eq. (29) or (30) we obtain the *true value* of the subchord, c, a little greater than 25; the *excess* is called the *correction* of the nominal length.

108. This correction for any given subchord bears an almost constant ratio to the excess of arc per station, whatever be the degree of curve. These ratios are shown in the following table for a series of subchords, and Table IV gives the length of actual arc per station for various degrees of curve. Subtracting 100 we have the excess of arc per station, and multiplying this *excess* by the *ratio* corresponding to the nominal length of subchord we obtain as a product the proper correction for the subchord.

TABLE OF THE RATIOS OF CORRECTIONS OF SUBCHORDS TO THE EXCESS OF ARC PER STATION

Nominal Length of Subchord.	Ratio.	Nominal Length of Subchord.	Ratio.	Nominal Length of Subchord.	Ratio.
0	.000	35	.307	70	.356
5	.050	40	.336	75	.327
10	.099	45	.358	80	.287
15	.147	50	.374	85	.235
20	.192	55	.383	90	.169
25	.234	60	.383	95	.092
30	.273	65	.374	100	.000

We observe that the largest correction is required by a subchord between 55 and 60 feet in length.

Example.—It is proposed to run a 14° curve with a 50-foot chain. What correction must be added to the chain?

$$D = 14^\circ \qquad \tfrac{1}{2}D = 7^\circ \qquad \tfrac{1}{2}d = \frac{50}{100} \times 7^\circ = 3^\circ.5 = 3^\circ\,30'$$

By eq. (30)

$$c = 100\,\frac{\sin 3^\circ\,30'}{\sin 7^\circ} = 50.093$$

Ans. Correction = .093.

Or, by Table IV, length of arc = 100.249
excess of arc = .249
and by above table, ratio for 50 feet = .374

Ans. Correction = product = .093

Example.—The P.C. of an 18° curve is fixed at + 55 beyond a station. What are the nominal and true valu the first subchord, and what the proper deflection?

$$\text{Nominal value} = 100 - 55 = 45 \text{ feet}$$

$$\text{Deflection} = \tfrac{1}{2}d = \frac{45}{100} \times 9° = 4°.05 = 4°\,03'$$

and by eq. (30)

$$\text{True value} = c = 100\frac{\sin 4°\,03'}{\sin 9°} = 45.148$$

Or, by Table IV, excess of arc = .412
by above table, ratio for 45 feet = .358

Correction = product = .147
Ans. True value of subchord = 45.147

Example.—The last deflection at the end of a 40° cur found to be 6° 30′. What are the nominal and true v of the last subchord?

Here $\frac{1}{2}d = 6°\,30'$, and by eq. (32)

$$\text{Nominal value, } c = 100\frac{6.5}{20} = 32.5 \text{ feet}$$

By eq. (30)

$$\text{True value, } c = 100\frac{\sin 6°\,30'}{\sin 20°} = 33.098 \text{ feet}$$

Or by Table IV, excess of arc 40° = 2.060
by above table, ratio for 32.5 feet = .290

Correction = product = .597
Nominal value of subchord = 32.5

True value = 33.097

109. The transitman keeps neat and systematic fi **notes** of all his operations with the transit, whether on gents or curves. The instrumental work is recorded on left-hand page of the transit book so as to read upwar the page, while the right-hand page is reserved for sket of prominent objects and for explanatory remarks. T the station numbers in the book advance in the same n ber as the stations on the ground, and there can be no *fusion as to the right* and left of the line in mak record. The complete topographic record is left for the topographer to make in a special book or on special paper.

FORM OF TRANSIT BOOK

Sta.	Point.	Plus.	Deflec.	Angle.	Δ	Calc. Bg.	Needle.
26							
25							
24	....	....	....	....	....	N1°26′ E	N1°30′E
⊙	P.T.	+15	6° 18′	12° 36′	33° 36′		
23	....	....	6				
22	....	....	4				
21	....	....	2°				
20	⊙	—	4° 48′	9° 36′			
19	....	....	2 48				
18	....	....	0° 48	....	$V =$	19 + 07.6	
⊙	....	+60	5° 42′	11° 24′	$T =$	432.6	
17	....	....	4 30	....	$L =$	840.0	
16	....	....	2 30				
15	....	....	0° 30′				
⊙	P.C.	+75	4° C. Right.				
14							
13	⊙	—				N32°10′W	N32°00′W

The Needle reading, as a rough check, may be recorded on the right-hand page if preferred. The position of the Vertex, length of Tangent and length of curve may appear in any vacant space. Double the last deflection on each long chord equals the angle subtended by it, and the sum of the angles equals Δ. The form given is for the first method of deflections and also applies to a compound curve. A slight change will be necessary for the second method.

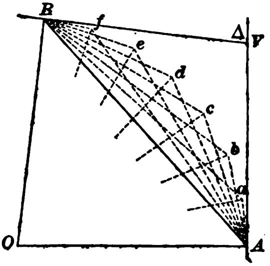

Fig. 7.

110. The stations on a curve may be located **by deflections only,** without linear measurements. For this purpose two transits are set at two transit points on the curve, as *A* and *B*, Fig. 7, and the proper deflections for any station are made with both instruments, the station being located by finding the intersection of the two lines of colli*mation.*

This method requires that the two transit points shall have been previously established, that their distance from each other shall be known, that they shall be visible from each other, and that they shall both command a view of the stations to be located. It is not therefore generally useful, but may be resorted to when certain stations fall where chaining cannot be accurately done, as in water or swamps. The chord joining the two transit points becomes, in fact, a base-line, and the deflections form a series of triangulations.

111. Metric Curves. In the Metric System the station length is 20 meters, or 65.617 feet. The consecutive station stakes are marked in even numbers only, so that ten times a station number gives the length of line to that point in meters.

Metric curves, laid out with 20 meter chords, are rated and identified, not by the central angle per station, D, but by the deflection angle per station, d_m, so that what the French *call* a 1° curve has, in fact, 2° of central angle per station. If R_m denote the metric radius, then

$$R_m = \frac{10}{\sin d_m} \qquad (16a)$$

from which all other parts of the metric curve may be calculated by the usual formulas, in metric units. Or we may derive the same values from our own tables. Thus, taking any value of d_m; $R_m = 0.2R$ for $D = 2d_m$, and on the same line of the table, $t_m = 0.2t$ and $m_m = 0.2_m$, the tangent offset and middle ordinate of a single chord of 20 meters.

A close approximation to the value of other parts may be had by observing that, for any given value of the central angle, Δ, and $D(= 2d_m)$, the tables give T, or C, or M, which multiplied by 0.2 produces T_m or C_m or M_m.

To find the equivalent curve; reduce R_m to feet, and from Table I take the corresponding value of D.

See Table XI for data on Metric Curves.

C. Location of Curves by Offsets

112. A curve may be located by linear measurement only, without angular deflections. There are four general methods, viz.:

By offsets from the chords produced,
By middle-ordinates,
By offsets from the tangents, and
By ordinates from a long chord.

To locate a curve by offsets from the chords produced.

When the curve begins and ends at a station.

113. Let A, Fig. 8, be the P.C. of a curve taken at a station, to locate the other stations, a, b, c, etc. The chords Aa, ab, bc, etc., each equal 100 feet, and since the angle $AOa = D$, the angle $VAa = \frac{1}{2}D$. (Table XLI, 20.) Taking an offset $ax = t$, perpendicular to the tangent, we have in the right-angled triangle Axa.

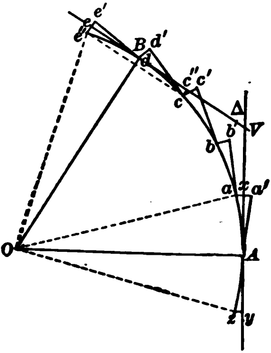

FIG. 8.

$$ax = Aa \times \sin \tfrac{1}{2}D$$

or

$$t = 100 \sin \tfrac{1}{2}D \qquad (34)$$

The offset t is called the tangent offset, and its value is given for all degrees of curve in Table I, col. 4.

If the curve were produced backward from A, 100 feet to station z, the offset zy would equal t; and if the chord zA were produced 100 feet from A to a', the offset $a'x$ would also equal t. Therefore the distance $aa' = 2t$, and the angle $aAa' = D$. So if we produce the chord Aa 100 feet to b', the distance $bb' = 2t$.

To lay out the curve, stretch the tape from A, keeping the forward end at a perpendicular distance, t, from the line of the tangent to locate station a. Then find the point b' by stretching the tape from a in line with a and A, and then stretching the tape again from a, fix its forward end at a distance from b' equal to $2t$. This gives station b. In the same way find other stations.

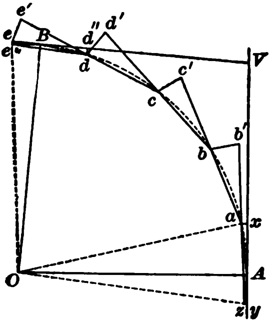

FIG. 9.

When the last station, as d, of the curve is reached, produce the curve one station farther to e''. Then the tangent through d is parallel to the chord ce'', and laying off t from c and e'' perpendicular to this chord, the tangent $c''e$ is found. If the work has been correctly done the tangent $c''e$ will coincide with the given tangent VB.

When the curve begins and ends with a subchord.

114. Let A, Fig. 9, be the P.C. and Aa the first subchord $= c$, and the angle $VAa = \frac{1}{2}d$, and let the offset $ax = t_1$. Then

$$t_1 = c \sin \tfrac{1}{2}d \qquad (3$$

Producing the curve backward to the nearest st we have another subchord $Az = (100 - c)$, and the angle $yAz = \frac{1}{2}(D - d)$, and putting the offset $yz = t_2$

$$t_2 = (100 - c) \sin \tfrac{1}{2}(D - d) \tag{36}$$

Laying off the two subchords on the ground, and making the proper offsets, t_1 and t_2, at the same time, we fix the position of the two stations a and z on the curve; after which we may produce the chord za 100 feet to b', and proceed as before until the curve is finished.

If the curve ends with a subchord, as dB, produce the curve to the first station beyond B, as e'', then calculate the two offsets for the two subchords Bd and Be'', and lay them off from d and e'' perpendicular to the supposed direction of the tangent. If the line $d''e$ so obtained coincides with the given tangent, VB, the work is correct.

115. We may find the values of t_1 and t_2 otherwise than by the formulas above, for in Fig. 8 we have shown that the angle $aAa' = aOA$, and since these triangles are isosceles, they are similar; therefore

Fig. 8,
$$OA : Aa :: Aa : aa'$$
$$R : 100 :: 100 : 2t$$

$\therefore$
$$t = \frac{(100)^2}{2R} \tag{37}$$

and similarly, Fig. 9,
$$t_1 = \frac{c^2}{2R} \tag{38}$$

Hence
$$t_1 : t :: c^2 : (100)^2$$

$\therefore$
$$t_1 = \frac{c^2 t}{(100)^2} \tag{39}$$

Thus t_1 may be found by multiplying the square of the subchord by the value of t given in Table I, and dividing the product by 10,000. As c is always less than 100, so t_1 is always less than t.

116. In eqs. (35), (38), and (39) it is customary to use the *nominal* values of c, and this can produce no error in t_1 exceeding 0.005, when the degree of curve does not exceed 10°. In the case of a very sharp curve, formula (41) is *preferable.*

To locate a curve by middle-ordinates.

When the curve begins and ends at a station.

117. In Fig. 10, let A be the P.C. at a station, and let a and z be the next stations on the curve either way from A. Then, since $zy = ax = t$, the chord za is parallel to the tangent AV, and $Ag = t$. Hence, having any two consecutive stations on the curve, as z and A, we may lay off the tangent offset t from A to g on the radius, and find the next station, a, 100 feet from A on the line zg produced. Then laying off $ah = t$ on the radius aO, a point on the line Ah produced and 100 feet from a will be the next station b.

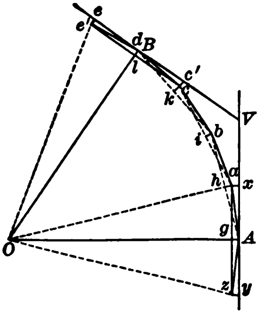

FIG. 10.

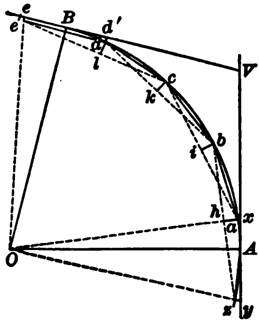

FIG. 11.

On reaching the end of the curve, the tangent is found precisely as described in the method by chords produced, § 113.

In Fig. 10, since vers $AOa = \frac{gA}{Oa} = \frac{t}{R}$, we have

$$t = R \text{ vers } D \tag{40}$$

When the curve begins or ends with a subchord.

118. Let A, Fig. 11, be the P.C., and a and z the nearest stations. Then $Aa = c$, the first subchord, and $aOA = d$, and by analogy, we have from the last equation, if $ax = t_1$ and $zy = t_2$

$$\left.\begin{aligned} t_1 &= R \text{ vers } d \\ t_2 &= R \text{ vers } (D - d) \end{aligned}\right\} \tag{41}$$

or eq. (39) may be used if preferred.

Having found the two stations, a and z, on the curve, lay off from the forward station a, $ah = t$ on the radius, and so continue the curve as described above.

When the end of the curve is reached, produce the curve to the next station beyond, and find the tangent by offsets as described in the previous method, § 114.

To locate a curve by offsets from the tangents.

When the curve begins at a station.

119. Let A, Fig. 12, be the P.C. at a station. Then the next station a is located by the tangent offset t, taken from Table I, or calculated by eq. (40). To calculate the distances and offsets for the following stations, b, c, etc., in the diagram draw lines through the points b, c, etc., parallel to the tangent AV, intersecting the radius AO in g', g'', etc., and draw the lines bx', cx'', etc., perpendicular to the tangent. Then

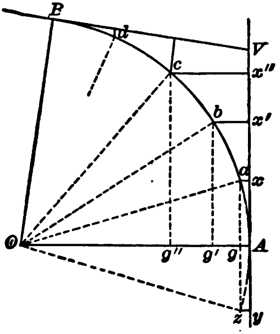

FIG. 12.

$$Ax' = g'b = Ob \sin bOA$$

or

$$\left.\begin{array}{rl} Ax' &= R \sin 2D \\ Ax'' &= R \sin 3D \\ \text{etc.} & \quad \text{etc.} \end{array}\right\} \qquad (42)$$

and

Also,

$$bx' = g'A = Ob \text{ vers } bOA$$

$$\begin{array}{ll} \text{or} & \left.\begin{array}{l} t' = R \text{ vers } 2D \\ t'' = R \text{ vers } 3D \\ \text{etc.} \qquad \text{etc.} \end{array}\right\} \\ \text{and} & \end{array} \qquad (43)$$

But these calculations may be avoided, for as twice ag equals the chord of two stations, so twice bg' equals the chord of four stations, and twice cg'' the chord of six stations, etc. So also as Ag is the middle-ordinate of two stations, Ag' is the middle-ordinate of four, and Ag'' the middle-ordinate of six stations, etc. Hence the rule:

The distance on the tangent from the tangent point to the perpendicular offset for the extremity of any arc is equal to one half the long chord for twice that arc; and the offset from the tangent to the extremity of any arc is equal to the middle-ordinate of twice that arc.

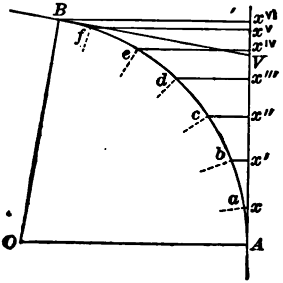

FIG. 13.

The long chords and middle-ordinates may be taken from Tables IV and VI for 2, 4, 6, 8, etc., stations, when the P.C. is at a station, or for 1, 3, 5, 7, etc., stations, when the P.C. is at + 50, or half a station.

If the offsets from the first tangent AV prove inconveniently long, the second half of the curve may be located from the other tangent BV, beginning at the point of tangent B, and closing on a station located from the first tangent.

When the curve begins with a subchord.

120. *If* d = the angle at center, subtended by the first *bchord,* we have for the distances on the tangent (Fig. 13)

$$\left.\begin{aligned} Ax &= R \sin d \\ Ax' &= R \sin (d + D) \\ Ax'' &= R \sin (d + 2D) \\ \text{etc.} &\qquad \text{etc.} \end{aligned}\right\} \qquad (44)$$

and for the offsets (Fig. 11)

$$\left.\begin{aligned} t_1 &= R \operatorname{vers} d \\ t' &= R \operatorname{vers} (d + D) \\ t'' &= R \operatorname{vers} (d + 2D) \\ \text{etc.} &\qquad \text{etc.} \end{aligned}\right\} \qquad (45)$$

If the first subchord equals 50 feet (nominal), then $d = \frac{1}{2}D$, and the Tables IV and VI may be used as explained above.

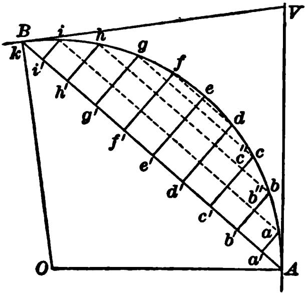

FIG. 14.

These tables may be used in any case, by adopting a temporary tangent through any station, and laying off the distances on this, and making the offsets from it.

When a curve is located by offsets the chain should be carried around the curve, if possible, to prove that the stations are 100 feet apart.

To locate a curve by ordinates from a long chord.

When the curve begins and ends at a station.

121. In Fig. 14 draw the long chord AB, joining the tangent points, and from this draw ordinates to all the stations on the curve. We then require to know the several distances on the long chord Aa', a'b', b'c', etc., and th *length* of ordinate at each point.

Let C = the long chord AB, then eq. (22)

$$C = 2R \sin \tfrac{1}{2}\Delta$$

If a is the second station and i next to the last on th
join ai, and let the chord $ai = C'$. Then since
$Aa = ik = D$, the angle at the center subtended
is $(\Delta - 2D)$.

$$\therefore \qquad C' = 2R \sin \tfrac{1}{2}(\Delta - 2D)$$

Again, if we join b and h the next stations and let b

$$C'' = 2R \sin \tfrac{1}{2}(\Delta - 4D)$$

and so on for other chords.
Since $Aa' = ki'$, $C = C' + 2Aa'$

$$\therefore \qquad Aa' = \frac{C - C'}{2}$$

Similarly,

$$a'b' = \frac{C' - C''}{2}$$

Thus we continue to find the distances up to the
of the curve, after which they repeat themselves in
order.

122. When the long chord C, subtends an *even nu
stations* (as 10 in Fig. 14), the middle-ordinate of th
is the ordinate of the middle station, as e. Since the
AB and ai are parallel, the ordinate $a'a$ or $i'i$ is ev
equal to the difference of the middle-ordinates o
chords.

Let M, M', M'', etc., be the middle-ordinates
chords C, C', C'', etc. Then eq. (23)

$$\begin{aligned} M &= R \text{ vers } \tfrac{1}{2}\Delta \\ M' &= R \text{ vers } \tfrac{1}{2}(\Delta - 2D) \\ M'' &= R \text{ vers } \tfrac{1}{2}(\Delta - 4D) \\ &\text{etc.} \qquad \text{etc.} \end{aligned}$$

And

$$\begin{aligned} a'a &= i'i = M - M' \\ b'b &= h'h = M - M'' \\ &\text{etc.} \qquad \text{etc.} \qquad \text{etc.} \end{aligned}$$

The values of the chords and middle-ordinates
ken at once from Tables IV and VI.

Example.— It is required to locate a 4° curve of ten stations by offsets from the long chord.

By Table IV:

		Diff.	½Diff.
10 sta.	$C = 980.014$	190.211	$95.105 = Aa' = ki'$
8 "	$C^{\text{i}} = 789.803$	194.059	$97.030 = a'b' = i'h'$
6 "	$C^{\text{ii}} = 595.744$	196.962	$98.481 = b'c' = h'g'$
4 "	$C^{\text{iii}} = 398.782$	198.904	$99.452 = c'd' = g'f'$
2 "	$C^{\text{iv}} = 199.878$	199.878	$99.939 = d'e' = f'e'$
0 "	$C^{\text{v}} = 000.000$		

From Table VI:

		Diff.	
10 sta.	$M = 86.402$	30.902	$= a'a = i'i$
8 "	$M^{\text{i}} = 55.500$	55.094	$= b'b = h'h$
6 "	$M^{\text{ii}} = 31.308$	72.459	$= c'c = g'g$
4 "	$M^{\text{iii}} = 13.943$	82.912	$= d'd = f'f$
2 "	$M^{\text{iv}} = 3.490$	86.402	$= e'e$
0 "	$M^{\text{v}} = 0.000$		

123. When the long chord C subtends an *odd number of stations*, the middle-ordinate will fall half-way between two stations, and need not be laid off.

If the ordinates near the middle of the curve prove inconveniently long, we may subtract $M - M'$, $M' - M''$, etc., and so obtain in Fig. 14 $a'a$, $b''b$, $c''c$, etc. We then lay off Aa', $a'a$, ab'', $b''b$, bc'', etc., turning a right angle at every point. The chain should be carried along the curve at the same time to make the stations 100 feet apart.

Example.—It is required to locate a 10° curve of nine stations by offsets from the long chord.

By Table IV:

		Diff.	½Diff.
9 sta.	811.314	153.209	$76.604 = Aa'$
7 "	658.105	173.205	$86.603 = a'b'$
5 "	484.900	187.938	93.969 etc.
3 "	296.962	196.962	98.481
1 "	100.000	100.000	50.000
0 "	0.000		

By Table VI:

		Diff.	
9 sta.	168.029	64.279	$= a'a$
7 "	103.750	50.000	$= b''b$
5 "	53.750	34.202	$= c''c$
3 "	19.548	17.365	etc.
1 "	2.183	2.183	
0 "	0.000		

124. The tables can be used equally well when the curve both begins and ends with **a half station;** also to locate half-station points throughout the curve, but in the latter case the numbers are taken from *consecutive* columns of the tables instead of from *alternate* columns, as in the above examples.

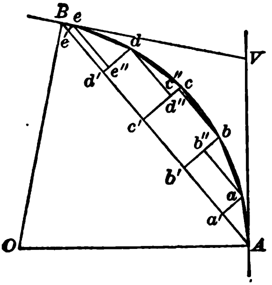

FIG. 15.

When the curve begins or ends with any subchord.

125. Let A, Fig. 15, be the P.C. and $Aa = c$ the first subchord, and d the angle it subtends at the center. In the diagram draw the long chord AB, and the ordinates to each station, and through each station draw a line parallel to AB, and let $AOB = \Delta$.

Since the angle $VAB = \frac{1}{2}\Delta$ and $VAa = \frac{1}{2}d$, the angle $aAB = \frac{1}{2}(\Delta - d)$. The deflection angle from the subchord Aa produced to the chord ab is $\frac{1}{2}(d + D)$, the deflection angle between any two consecutive chords of 100 feet is $\frac{1}{2}(D + D) = D$. Therefore the angle

$$
\begin{aligned}
bab'' &= \tfrac{1}{2}(\Delta - d) - \tfrac{1}{2}(d + D) = \tfrac{1}{2}(\Delta - 2d - D)\\
cbc'' &= \tfrac{1}{2}(\Delta - 2d - D) - \tfrac{1}{2}(2D) = \tfrac{1}{2}(\Delta - 2d - 3D)\\
cdd'' &= \tfrac{1}{2}(\Delta - 2d - 3D) - \tfrac{1}{2}(2D) = \tfrac{1}{2}(\Delta - 2d - 5D)\\
&\text{etc.} \qquad \text{etc.} \qquad \text{etc.}
\end{aligned}
$$

Solving the several right-angled triangles we have, Fig. 15.

$$
\left.
\begin{aligned}
Aa' &= c.\ \ \cos \tfrac{1}{2}(\Delta - d)\\
ab'' &= 100 \cos \tfrac{1}{2}(\Delta - 2d - D)\\
bc'' &= 100 \cos \tfrac{1}{2}(\Delta - 2d - 3D)\\
dd'' &= 100 \cos \tfrac{1}{2}(\Delta - 2d - 5D)\\
&\text{etc.} \qquad\qquad \text{etc.}
\end{aligned}
\right\} \tag{46}
$$

And also

$$
\left.
\begin{aligned}
a'a &= c.\ \ \sin \tfrac{1}{2}(\Delta - d)\\
b''b &= 100 \sin \tfrac{1}{2}(\Delta - 2d - D)\\
c''c &= 100 \sin \tfrac{1}{2}(\Delta - 2d - 3D)\\
d''c &= 100 \sin \tfrac{1}{2}(\Delta - 2d - 5D)\\
&\text{etc.} \qquad\qquad \text{etc.}
\end{aligned}
\right\} \tag{47}
$$

When the middle point of the curve is passed the minus quantities in the parentheses become greater than Δ, making the parentheses negative, and, therefore, the sines negative, and indicating that such values as are determined by them must be laid off *toward* the long chord AB.

By a proper summation of the quantities determined by eqs. (46) and (47) we obtain the distances Aa', Ab', Ac', etc., and the ordinates $a'a$, $b'b$, $c'c$, etc., and the curve may be located accordingly. It is well to make all the necessary calculations before beginning to lay down the lines on the ground, thus avoiding confusion and mistakes.

Example.—The P.C. of a 3° 20′ curve is fixed at + 25 feet beyond a station, and the central angle is 16° 24′ = Δ. It is required to locate the curve by ordinates from the long chord.

We have $c = 100 - 25 = 75$ and $d = 2°\,30'$ and $D = 3°\,20'$. Hence, eqs. (46)

$$
\begin{array}{lll|l}
Aa' = & 75 \cos & 6°\,57' = 74.449 & 74.449 = Aa'\\
ab'' = & 100 \cos & 4°\,02' = 99.752 & 174.201 = Ab'\\
bc'' = & 100 \cos & 0°\,42' = 99.993 & 274.194 = Ac'\\
d''d = & 100 \cos & (-2°\,38') = 99.894 & 374.088 = Ad'\\
e''e = & 100 \cos & (-5°\,58') = 99.458 & 473.546 = Ae'\\
e'B = & 17 \cos & (-7°\,55') = 16.838 & 490.384 = AB
\end{array}
$$

By eqs. (47)

$$\begin{array}{rlr|l}
a'a = & 75 \sin \ 6^\circ 57' = & 9.075 & 9.075 = a'a \\
b''b = & 100 \sin \ 4^\circ 02' = & 7.034 & 16.109 = b'b \\
c''c = & 100 \sin \ 0^\circ 42' = & 1.222 & 17.331 = c'c \\
cd'' = & 100 \sin (-2^\circ 38') = & -\ 4.594 & 12.737 = d'd \\
de'' = & 100 \sin (-5^\circ 58') = & -\ 10.395 & 2.342 = e'e \\
ee' = & 17 \sin (-7^\circ 55') = & -\ 2.341 & 0.000 \quad \ldots
\end{array}$$

The same formulas can be used when the curve begins at a station by making $c = 100$ and $d = D$.

126. The methods of locating curves by linear measurements do not require the use of a transit, although one may be used to advantage for giving true lines, turning right angles, etc. When a transit is not used the alinements should be made across plumb-lines suspended over the exact points previously marked on top of the stakes. **A right angle** may easily be obtained, without an instrument, by laying off on the ground the three sides of any of the right-angled triangles represented in the following table (or any multiples of them), always making the *base* coincide with the given line.

TABLE OF RIGHT-ANGLED TRIANGLES

Base.	Hypothenuse.	Perpendicular.
4	5	3
12	13	5
20	29	21
24	25	7
40	41	9
60	61	11
84	85	13

D. Obstacles to the Location of Curves

127. *To locate a curve joining two tangents when the* **intersection** *V* **is inaccessible.** Fig. 16.

From any transit point p on one tangent run a line pq to intersect the other tangent; measure pq and the angles it makes with the tangents. Then the sum of the deflections at p and q equals the central angle Δ. Solve the triangle *pqV and find Vp.* Having decided on the radius R of the *rve, calculate* the tangent distance VA by eq. (21), and lay off from p the distance $pA = VA - Vp$ to locate the point of curve. The point p being assumed at random, Vp may exceed VA, in which case the difference pA is to be laid off *toward* V.

In case obstacles prevent the direct alinement of any line pq, it may be replaced by two or more lines, and the distances Vp and Vq found. There will be as many triangles to solve as there are courses. The algebraic sum of the several deflections will equal Δ.

128. *To locate a curve when the* **point of curve is inaccessible.** Fig. 17.

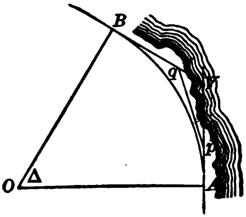

FIG. 16.

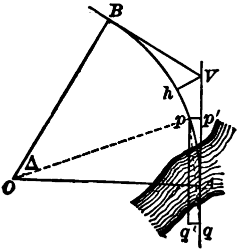

FIG. 17.

Assume any distance Ap on the curve which will reach to an accessible point p. Then by eq. (19) the angle

$$pOA = \frac{D \times Ap}{100}$$

From the figure,

$$Ap' = R \sin pOA$$

$$p'p = R \operatorname{vers} pOA$$

$$Vp' = VA - Ap'$$

Measure Vp' and $p'p$ to locate a transit point at p; and measure an equal offset from some transit point on the tangent, as qq'. This gives a line pq', parallel to the tangent, from which deflect at p an angle equal to pOA for the direction of a tangent through the point p.

Instead of measuring the second offset qq' we may deflect from pq an angle found by $\tan qpq' = \frac{pp'}{qp'}$, and so obt the line pq' parallel to the tangent. Or we may deflect from pV the angle found by tan $pVp' = \frac{pp'}{Vp'}$ to obtain the line $q'p$ produced, from which the tangent to the curve at p is found as above.

Again, we may lay off from V, the external distance Vh found by eq. (24) or Table III on a line bisecting the angle AVB. This gives us h, the middle point of the curve, and a line at right angles to hV is tangent to the curve at h, from which the curve may be located in either direction.

129. *To locate a curve when both the* **Vertex** *and* **Point of curve are inaccessible.** Fig. 18.

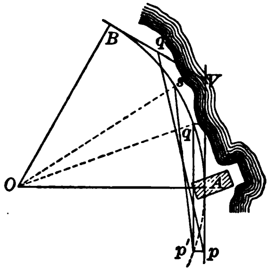

FIG. 18.

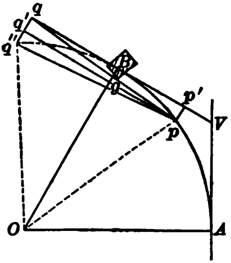

FIG. 19.

From any point p on the tangent run a line pq' to the other tangent, and so determine pA as in § 127. Suppose the curve produced backward to p' on the perpendicular offset pp'.

Then

$$\sin p'OA = \frac{pA}{R}, \text{ and } pp' = R \text{ vers } p'OA$$

Having located the point p', a parallel chord $p'q$ may be laid off, giving a point q on the curve, since $p'q = 2 \times pA$. At q deflect from qp' an angle equal to $p'OA$ for a tangent to the curve at q.

If any obstacle prevents using the chord $p'q$, any other chord as $p's$ may be used, by deflecting from $p'q$ the angle $qp's = \frac{1}{2}(qOs)$ and laying off its length,

$$p's = 2R \sin (p'OA + qp's)$$

At s a deflection from the chord sp' of $(p'OA + qp's)$ will give the tangent at s.

If obstacles prevent the use of any chord, the methods described in § 131 may be resorted to.

130. *To pass from a curve to the forward tangent when the* **Point of Tangent is inaccessible.** Fig. 19.

From any transit point p on the curve, near the end of the curve, run a chord parallel to the tangent. The middle point g of the chord will be on the radius through the point of tangent B. At any convenient point beyond this an offset equal to $pp' = R$ vers pOB may be made to the tangent, and at some other point an equal offset will fix the direction of the tangent.

Otherwise, if an unobstructed line pq can be found intersecting the tangent at a reasonable distance from B, measure the angle $q'pq = pqp'$, and lay off the distance

$$pq = \frac{pp'}{\sin q'pq}$$

to fix the point q. Then

$$Bq = p'q - p'B = pp' \cot q'pq - R \sin pOB.$$

Otherwise, assume an arc of any number of stations from p to q'' on the curve produced, and take the length of chord from Table IV. Lay off pq'', and from q'' lay off $q''q = R$ vers $q''OB$, perpendicular to the tangent, to locate q. The angle $pq''q = 90° - q'pq''$, and the distance $qB = R \sin q''OB$.

131. *To pass an* **obstacle on a curve.** Fig. 20.

From any transit point A' on the curve take the direction of a long chord which will miss the obstacle, as $A'B'$. The length of this chord is $2R \sin V'A'B'$, $V'A'$ being tangent to the curve at A' (see eq. (22)), and by measuring this distance, the point B' on the curve is obtained. If the angle V' A' B' is made equal to the deflection for an exact number of stations, the chord may be taken from Table IV.

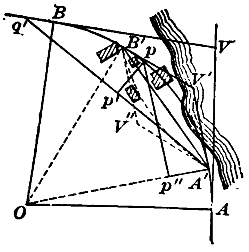

FIG. 20.

If the chord which will clear the obstacles would be too long for convenience, as $A'q'$, we may measure a part of it as $A'p'$, and then, by an ordinate to some station, regain the curve at p. The distance on the curve from A' to p being assumed, the distances $A'p'$ and $p'p$ are calculated by the methods given in § 121 to § 125. If $p'p$ can be made a middle-ordinate the work will be much simplified. If more convenient the middle-ordinate may first be laid off from A' to p'', and the half chord afterwards measured from p'' to locate p.

Again, we may calculate the auxiliary tangent $A'V'$ for any assumed length of curve $A'B'$, and lay off the distance $A'V'$ and $V'B'$, deflecting at V' an angle equal to twice $V'A'B$. But if the point V' should prove inaccessible, we may conceive the auxiliary tangents to be revolved about the chord $A'B'$ as an axis, so that V' will fall at V'', and the lines $A'V''$ and $V''B'$ may be laid out accordingly. If these in turn meet obstructions, we may run a curve from A' to B' of same radius as the given curve, but tangent to $A'V''$ and $V''B'$.

Again, the entire curve or any portion of it may be laid out by offsets from the tangents, or by ordinates from a long chord, as already explained, § 119 to § 126.

In case any distance on a curve must be measured by triangulation, as in crossing a stream, a long chord may be chosen, either end of which is accessible, and the triangulation is then performed with respect to this chord or a part of it, as upon any other straight line.

SPECIAL PROBLEMS IN SIMPLE CURVES

132. *Given: a curve joining two tangents, to find the change required in the radius* **R**, *and external distance* **E**, *for an assumed change in the value of the tangent distance* **T**. Fig. 21.

$$\text{Let } T = AV = VB \qquad \text{and } T' = A'V = VB'$$

$$R = AO \qquad\qquad R' = A'O',$$

$$E = VH \qquad\qquad E' = VH'$$

Then $T - T' = AA'$ = the given change.

By eq. (25) $$R = T \cot \tfrac{1}{2}\Delta$$

$$R' = T' \cot \tfrac{1}{2}\Delta$$

$$\therefore \qquad OG = R - R' = (T - T') \cot \tfrac{1}{2}\Delta \tag{48}$$

By eq. (26), similarly,

$$HH' = E - E' = (T - T') \tan \tfrac{1}{2}\Delta \tag{49}$$

Eqs. (48) (49) give the changes in R and E for any change in T. When T is increased R and E will be increased also, and *vice versa.*

Example.—A 4° curve joins two tangents, making an angle of $38° = \Delta$, and it is necessary to shorten the last tangent distance 80 feet. What will be the change in the radius and in the external distance?

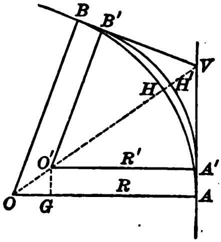

FIG. 21.

Eq. (48)	$T - T' = 80$		log 1.903090
	$\tfrac{1}{2}\Delta$	19°	log cot 0.463028
Ans.	$R - R'$	232.34	log 2.366118
	R	1432.69	
	$R' =$	1200.35	or about $4° 46' = D'$.

If the tangent distance had been increased 80 feet we should add the above to R.

$$\therefore \qquad R' = 1665.03 \quad \text{or about } 3° 26' = D'$$

Eq. (49)	$T - T' = 80$		log 1.903090
	$\tfrac{1}{2}\Delta$	9° 30′	log tan 9.223607
Ans.	$E - E'$	13.387	log 1.126697

133. *Given: a curve joining two tangents, to find the change required in the radius* **R,** *and tangent distance* **T,** *for any assumed change in the value of the external distance* **E.** Fig. 21.

We suppose HH' given, to find OG and AA'.

By eq. *(24)* $$E = R \text{ ex sec } \tfrac{1}{2}\Delta$$

$$E' = R' \text{ ex sec } \tfrac{1}{2}\Delta$$

$$\therefore \qquad OG = R - R' = \frac{E - E'}{\text{ex sec } \frac{1}{2}\Delta} \tag{50}$$

By eq. (49)

$$AA' = T - T' = (E - E') \cot \tfrac{1}{2}\Delta \tag{51}$$

Example.—A 4° curve joins two tangents, making an angle of 38° = Δ, and it is necessary to bring the middle point of the curve 25 feet nearer the vertex V. What changes are required in the radius and point of curve?

Ans. From eq. (50), $R - R' = 433.87$; then $R' = 998.82$ and $D' = 5° 44'$ about.

From eq. (51), $T - T' = 149.39$.

But if the point H, Fig. 21, were to be moved 25 feet further from the vertex V, then

$$R' = 1866.56 \text{ or about } 3° 04' = D'$$

and the P.C. will be moved 149.39 feet further from the vertex.

It is preferable to assume some radius from Table I near the value of R' found as above, and from this calculate the value of T' by eq. (21).

134. *Given: a curve joining two tangents, to find the change made in the tangent distance* **T,** *and external distance* **E,** *by any assumed change in the value of the radius* **R.** Fig. 21.

By eq. (48)

$$AA' = T - T' = (R - R') \tan \tfrac{1}{2}\Delta \tag{52}$$

By eq. (50)

$$HH' = E - E' = (R - R') \text{ ex sec } \tfrac{1}{2}\Delta \tag{53}$$

The changes calculated by eqs. (52) (53) will be added to or subtracted from T and E respectively, according as the radius is increased or diminished.

135. Since for a constant value of the central angle Δ, the homologous parts of any two curves are proportional to each other, we may write at once

$$\left.\begin{aligned} R' &= R\frac{T'}{T} = R\frac{E'}{E} = R\frac{C'}{C} = R\frac{M'}{M} \\ T' &= T\frac{R'}{R} = T\frac{E'}{E} = T\frac{C'}{C} = T\frac{M'}{M} \\ &\text{etc.} \qquad \text{etc.} \qquad \text{etc.} \end{aligned}\right\} \tag{54}$$

136. *Given: a curve joining two tangents, to change the position of the* **Point of curve** *so that the curve may end in a* **parallel tangent.** Fig. 22.

Let AB be the given curve, AV, VB the tangents, and $V'B'$ the parallel tangent. Then VV' is the distance from one vertex to the other; and since there is no change in the form or dimensions of the curve, we may conceive it to be moved bodily, parallel to the line AV, until it touches the line $V'B'$, when every point of the curve will have moved a distance equal to VV'. Hence $AA' = OO' = BB' = VV'$. Therefore, run a line from B parallel to AV, intersecting the new tangent in B', measure BB', and lay off the distance from A to find A'. In the figure the new tangent is taken outside the curve, and so A' falls beyond A, but if the new tangent were taken inside the curve at $V''B''$, the new P.C. would fall back of A at some point A''.

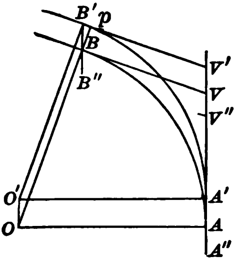

FIG. 22.

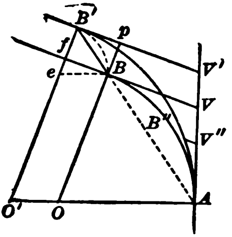

FIG. 23.

If the parallel tangent is defined by a perpendicular offset from B, as Bp, since the angle $BB'p = \Delta$

$$AA' = BB' = \frac{Bp}{\sin \Delta} \tag{55}$$

137. *Given: a curve joining two tangents, to find the* **radius** *of a curve that, from the same Point of curve, will end in a* **parallel tangent.** Fig. 23.

Let AB be the given curve, AV, VB the tangents, and $V'B'$ the parallel tangent; and let $AO = R$ and $AO' = R'$.

Since the *central* angle Δ remains unchanged, the angl
$\frac{1}{2}\Delta$ *between the tangent* and long chord remains unchange

therefore $V'AB' = VAB$, and the new point of tangent is on the long chord AB produced. Find on the ground the intersection of $V'B'$ with AB produced and measure BB'. In the diagram draw Be parallel to AO, then $BeB' = \Delta$, and by eq. (22)

$$BB' = 2Be \sin \tfrac{1}{2}\Delta$$

but

$$Be = OO' = R' - R$$

$$\therefore \qquad R' = R \pm \frac{BB'}{2 \sin \frac{1}{2}\Delta} \tag{56}$$

Use the lower sign when the parallel tangent cuts the chord AB at some point B'', since R' will evidently be less than R.

If the parallel tangent is defined by a perpendicular offset, as $Bp = B'f$; since $BeB' = \Delta$

$$Bp = Be \text{ vers } \Delta = (R' - R) \text{ vers } \Delta$$

$$R' = R \pm \frac{Bp}{\text{vers } \Delta} \tag{57}$$

Add or subtract as explained above.

If the long chord $C = AB$ is known, then the new long chord $C' = AB'$ or $AB'' = C \pm BB'$, and by eq. (54)

$$R' = R\frac{C \pm BB'}{C} \tag{58}$$

138. *Given: a curve joining two tangents, to change the* **radius,** *and also the* **Point of curve,** *so that the new curve may end in a* **parallel tangent directly opposite** *the given Point of tangent.* Fig. 24.

Let AB be the given curve, AV, VB the tangents, $V'B'$ the parallel tangent, and B' the given tangent point on the radius OB produced.

In the diagram, produce the tangent AV and the radius OB to intersect at K. Then

$$BK = R \text{ ex sec } \Delta$$

$$B'K = R' \text{ ex sec } \Delta$$

Subtracting we have

$$BB' = (R - R') \text{ exsec } \Delta$$

$$\therefore \qquad R - R' = \frac{BB'}{\text{ex sec}\,\Delta} \tag{59}$$

from which R' is easily determined, as in §§ 132 and 133.

To find the change AA' of the P.C., in the diagram draw $O'G$ parallel to $A'A$; then

$$O'G = OG \tan \Delta$$

or

$$AA' = (R - R') \tan \Delta \tag{60}$$

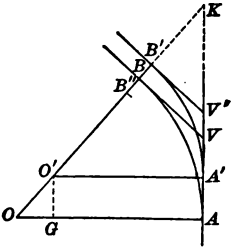

Fig. 24.

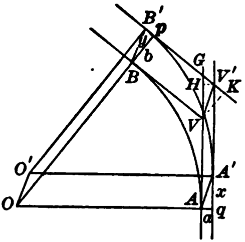

Fig. 25.

By substituting the value of $(R - R')$ from eq. (59) and observing Table XLII, 42, we have

$$AA' = BB' \times \cot \tfrac{1}{2}\Delta \tag{61}$$

Observe that eqs. (59), (60), and (61) may be derived directly from eqs. (50), (52), and (51) respectively by writing Δ for $\tfrac{1}{2}\Delta$.

139. *Given: a curve joining two tangents; to find the* **new tangent points** *after* **each tangent** *has been* **moved parallel to itself** *any distance in either direction.* Fig. 25.

Let A and B be the given tangent points, and A' and B' the new tangent points required. Let the known perpendicular distances $Aq = a$, and $Bp = b$. We then require the unknown parallel distances $qA' = x$ and $pB' = y$.

Since the form and dimensions of the curve remain unchanged we may conceive the curve to be moved bodily into its new position on lines parallel and equal to the line VV' joining the vertices. Then AA' = OO' = BB' = VV'

In the diagram draw VK parallel and equal to Bp = b a

$V'H$ parallel and equal to $Aq = a$. Then $VH = qA' = x$, and $V'K = B'p = y$. Since $VGV' = \Delta$, we have

$$VG = \frac{b}{\sin\Delta} \text{ and } GH = \frac{a}{\tan\Delta}$$

and since

$$VH = VG - GH = x$$

Similarly

$$\left.\begin{aligned} x &= \frac{b}{\sin\Delta} - \frac{a}{\tan\Delta} \\ y &= \frac{b}{\tan\Delta} - \frac{a}{\sin\Delta} \end{aligned}\right\} \qquad (62)$$

When the new tangents are outside of the given curve, the offsets a and b are considered positive; if either new tangent were inside of the given curve its offset would be considered negative. In solving eqs. (62) if x and y are found to be positive they are to be laid off *forwards* from q and p, as in Fig. 25; if either is found to be negative it is to be laid off in the opposite direction.

Example.—A certain curve has a central angle of $50° = \Delta$, and it is proposed to move the first tangent *in* 20 feet and the second tangent *out* 12 feet. Required, the distances on the tangents from the old tangent points to the new. Fig. 26.

Here $a = -20$ and $b = +12$

$+b$	12		1.079181	$-a$	20		1.301030
Δ	50°	log sin	9.884254	Δ	50°	log tan	0.076186
	15.665		1.194927	$-$	16.782		1.224844

$$\therefore \qquad x = 15.665 - (-16.782) = +32.447$$

$+b$	12		1.079181	$-a$	20		1.301030
Δ	50°	log tan	0.076186	Δ	50°	log sin	9.884254
	10.069		1.002995	$-$	26.108		1.416776

$$\therefore \qquad y = 10.069 - (-26.108) = +36.177$$

For $+a$ and $-b$ $\quad \begin{cases} x = -32.450 \\ y = -36.177 \end{cases}$

For $+a$ and $+b$ $\quad \begin{cases} x = -1.120 \\ y = -16.039 \end{cases}$

For $-a$ and $-b$ $\begin{cases} x = +\ \ 1.120 \\ y = +15.939 \end{cases}$

If we have a and x given to find b and y: Solving eqs. (62) for b and y we obtain

$$\left.\begin{aligned} b &= x \sin \Delta + a \cos \Delta \\ y &= x \cos \Delta - a \sin \Delta \end{aligned}\right\} \qquad (63)$$

In which the algebraic signs of the quantities must be observed as above.

140. *Given: a curve joining two tangents, to find a new* **Radius** *and new position of the* **Point of curve,** *such that the curve may end at the same point as before, but with a given change in the* **direction** *of the forward tangent.* Fig. 27.

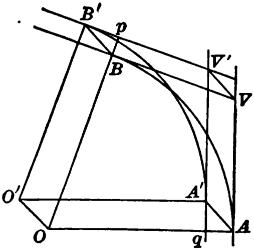

Fig. 26.

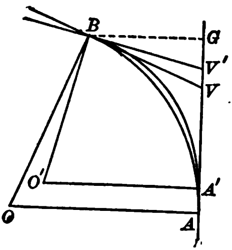

Fig. 27.

Let AB be the given curve, AV, VB the given tangents, $V'B$ the new tangent, and VBV' the given change in direction. Let $\Delta' = \Delta + VBV'$.

In the diagram draw BG perpendicular to AV produced; then

$$BG = R \text{ vers } \Delta$$

$$= R' \text{ vers } \Delta'$$

Hence

$$R' = R \frac{\text{vers } \Delta}{\text{vers } \Delta'} \qquad (64)$$

and

$$AA' = AG - A'G = R \sin \Delta - R' \sin \Delta' \qquad (65)$$

In *the figure the* change in direction of tangent makes Δ *greater than* Δ; therefore V' falls beyond V, and A' beyo

A; but if the change made Δ' less than Δ, then V' and A' would fall behind V and A respectively, and R' would be greater than R.

The same formulas apply to the converse problem in which B is taken as the point of curve, and A and A' as points of tangent.

141. *Given: a curve joining two tangents, to find the change in the* **Point of curve** *when the forward tangent takes a new* **direction** *from the* **vertex, V.** Fig. 28.

By eq. (21)

$$VA = R \tan \tfrac{1}{2}\Delta, \quad VA' = R \tan \tfrac{1}{2}\Delta'$$

$$\therefore \qquad AA' = R\,(\tan \tfrac{1}{2}\Delta - \tan \tfrac{1}{2}\Delta') \qquad (66)$$

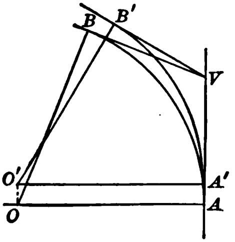

FIG. 28.

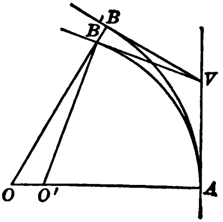

FIG. 29.

142. *Given: a curve joining two tangents, to find the new* **radius, R',** *when the forward tangent takes a new* **direction** *from the* **vertex, V.** Fig. 29.

By eqs. (21) (25)

$$VA = R \tan \tfrac{1}{2}\Delta, \quad R' = VA \cot \tfrac{1}{2}\Delta'$$

$$\therefore \qquad R' = R \tan \tfrac{1}{2}\Delta \cot \tfrac{1}{2}\Delta' \qquad (67)$$

143. *Given: a curve joining two tangents, and a given change in the* **direction** *of the forward tangent from the vertex, to find the* **radius** *and* **point of curve** *of a curve that shall pass at the* **same distance, VH,** *from the vertex.* Fig. 30.

Let AB be the given curve, BVB' the given change in direction of tangent, and $VH' = VH$. Let $\Delta' = \Delta + BVB'$, *n eq. (24)*

$$VH = R \text{ ex sec } \tfrac{1}{2}\Delta = VH' = R' \text{ ex sec } \tfrac{1}{2}\Delta'$$

$$\therefore \qquad R' = R\frac{\text{ex sec } \frac{1}{2}\Delta}{\text{ex sec } \frac{1}{2}\Delta'} \qquad (68)$$

By eq. (28)

$$VA = VH \cot \tfrac{1}{2}\Delta, \quad VA' = VH' \cot \tfrac{1}{2}\Delta'$$

$$\therefore \qquad AA' = VH\left(\cot \tfrac{1}{2}\Delta - \cot \tfrac{1}{2}\Delta'\right) \qquad (69)$$

But in case $\Delta' = \Delta - BVB'$, AA' becomes negative and must be laid off backward from A.

Example.—Given a 2° curve, $\Delta = 80°$ and $BVB' = -10°$ $\therefore \Delta' = 70°$.

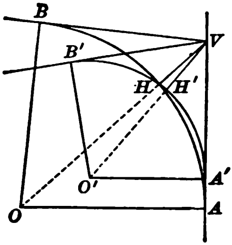

FIG. 30.

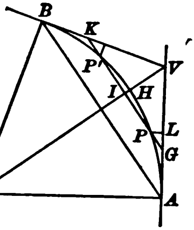

FIG. 31.

Ans. From eq. (68), $D' = 1° 27'$ nearly, and from eq. (69), $AA' = -371.08$, which means that A' must be laid off backward from A.

144. *Given: two indefinite tangents, a point situated between them, and the angle* Δ*, to find the radius* **R**, *and tangent distance* **T** *of a curve joining the tangents which shall pass through the* **given point.** Fig. 31.

If the given point is on the bisecting line VO, as H, measure $VH = E$, and find R and T as in §§ 97, 98.

When the given point, as P is not on the bisecting line VO; if a line GK is passed through P perpendicular to VO, it will be parallel to any long chord, as AB, and the angle $VGK = \frac{1}{2}\Delta$. The curve passing through P will intersect GK in some other point P'; the line GK is bisected by the line VO at I, and $PI = P'I$, If the given point P is located by a perpendicular offset from the tangent, as PL; in the triangle PLG, $LG = PL \cot \frac{1}{2}\Delta$. Lay off LG, and at G deflect $VGK = \frac{1}{2}\Delta$, and measure GP and PK. Since by Geom. (Table XLI, 24) $\overline{GA}^2 = GP' \times GP$, and $GP' = PK$;

$$\therefore \qquad GA = \sqrt{GP \times PK} \qquad (70)$$

Lay off GA; and A is the Point of curve, $AV = T$, and $R = AV \cot \frac{1}{2}\Delta$.

If the given point were located by an offset from BV, find B first, and make $VA = BV$.

If the given point P is located by a perpendicular offset IP from the bisecting line VO; produce IP to intersect the tangent at G and measure PG. Since $P'G = GP + 2PI$

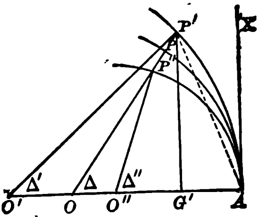

FIG. 32.

$$\therefore \qquad GA = \sqrt{GP(GP + 2PI)} \qquad (71)$$

whence we have the point of curve A, as before.

145. *Given:* a curve, AP, and the **radial offset PP'** *to find a curve which shall pass through the* **point P'**, *starting from the same point of curve* **A.** Fig. 32.

Let $b = PP'$, and in the diagram draw $P'G'$ parallel to the common tangent AX, and join AP'. Then

$$P'G' = (R \pm b) \sin \Delta$$

$$G'A = R - (R \pm b) \cos \Delta$$

$$\tan \tfrac{1}{2}\Delta' = \tan G'P'A'$$

dir[illegible] $= \dfrac{G'A}{P'G'} = \dfrac{R}{(R \pm b) \sin \Delta} - \cot \Delta \qquad (72)$

$$R' = O'P' = \frac{P'G'}{\sin \Delta'} = \frac{(R \pm b) \sin \Delta}{\sin \Delta'} \qquad (73)$$

When the offset is *outward* use $R + b$, when it is *inward use* $R - b$.

Example.—Given: a 3° curve of 16 stations and a radial offset of 205 feet inward from the P.T. to find the radius of the curve passing through the extremity of the offset.

Ans. $\Delta = 48°$ and $b = 205$. From eq. (72), $\Delta' = 62° 31'$ and from eq. (73) and Table I., D' = about 4° 01′.

If the same offset were made *outside* of the curve we should find R' log 3.438350, or about a 2° 05′ curve.

This solution is inconveniently long for ordinary field practice. When the offset is small compared with the length of curve, we may use the following

Approximate Rule: Divide twice the offset b by the length of curve, look for the quotient in the table of nat. sines, and take out the corresponding angle, which multiply by 100, and divide by the length of curve. The *quotient* is the *correction* for the given degree of curve; to be *subtracted* when the offset is made *outward*, and *added* when the offset is made *inward.*

This rule is expressed by the formula

$$D' = D \mp \frac{100}{L} \sin^{-1} \frac{2b}{L} \qquad (74)$$

For the necessary change in Δ is equal to twice the angle PAP' which is expressed by $\sin^{-1} \frac{2b}{L}$, and to reduce this to Degree of curve we multiply by $\frac{100}{L}$, as in eq. (20). Whence, eq. (74) results.

Taking the same example, we have

$$\frac{2b}{L} = \sin 14° 51'$$

$$\text{and correction} = 14° 51' \times \frac{100}{1600} = \mp 0° 56'$$

Hence $D' = 3° 56'$ or $D' = 2° 04'$.

THE VALVOID

146. *Given: any number of circular curves of equal length L, all starting from a common point of curve A, in a common tangent AX, to find the* **equation of the curve** *joining their extremities.* Fig. 33.

Let AP be any one of the given curves;

R = its radius AO;
D = its degree of curve;
Δ = its central angle AOP;
C = its long chord AP.

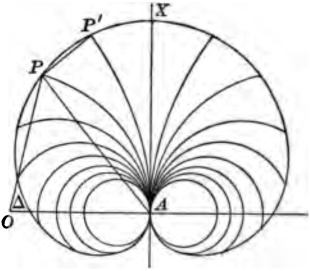

Fig. 33.

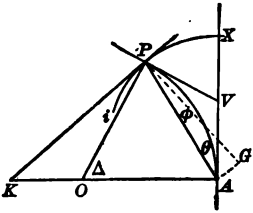

Fig. 34.

By substituting the value of R from eq. (16) in eq. (22) we have

$$C = 100\frac{\sin \frac{1}{2}\Delta}{\sin \frac{1}{2}D} \qquad (75)$$

Substituting in this the value of D from eq. (20) and letting (theta) $\theta = \frac{1}{2}\Delta$, (rho) $\rho = \frac{C}{100}$ and $N = \frac{L}{100}$, we have for the polar equation of the required curve

$$\rho = \frac{\sin \theta}{\sin \frac{\theta}{N}} \qquad (76)$$

in which ρ is the radius vector AP, θ the variable angle XAP, the unit of measure is one side of the inscribed polygon [illegible] which the circular curve AP is measured, and N the number [illegible] sides in the length of the curve AP. By the [illegible] the problem N is constant, but θ may have any value whatever. If we let θ vary from 0° to + 180° and from 0° to −180° the point X will describe the curve $XP'PA$ shown in the figure, which is called the *Valvoid* from its resemblance to the shell of a bivalve. All circular curves tangent to AX at A and having a length $L = AX$ will terminate in the valvoid, and the line PP' joining the extremities of any two of them is a chord of the valvoid.

147. *To find a* **tangent to the valvoid** *at any point* **P.** Fig. 34. See Appendix.

Differentiating eq. (76)

$$\frac{d\rho}{d\theta} = \rho\left(\cot\theta - \frac{1}{N}\cot\frac{\theta}{N}\right) \qquad (77)$$

which is essentially negative, since ρ is a decreasing function of θ.

Let (phi) $\phi = APG$, the angle between the radius vector and the normal PG.

$$\therefore \qquad \tan\phi = \frac{1}{N}\cot\frac{\theta}{N} - \cot\theta \qquad (78)$$

The line PK perpendicular to PG is tangent to the valvoid at P, and PV perpendicular to PO is tangent to the curve AP.

Then $APV = \theta$ and $VPG = \theta - \phi$, and letting $i = OPK = VPG$,

$$\therefore \qquad i = \theta - \phi = \tfrac{1}{2}\Delta - \phi \qquad (79)$$

Therefore, to obtain the direction of a tangent to the valvoid at any point P, deflect from the radius PO an angle equal to $i = (\tfrac{1}{2}\Delta - \phi)$, on the side of PO farthest from the point of curve A.

The value of i may be found by eqs. (78) (79), but we are saved this somewhat tedious calculation by the use of Table VII, 1, which contains values of the ratio $\frac{i}{\Delta} = u$ for various values of Δ, and length of curve L. Multiplying Δ by the proper tabulated number gives the value of $i = OPK$ at once; or

$$i = (\tfrac{1}{2}\Delta - \phi) = u\Delta \qquad (80)$$

148. *To find the* **radius of curvature** of the valvoi *at any point* **P.** See Appendix.

Differentiating eq. (77) we have

$$\frac{d^2\rho}{d\theta^2} = \rho\left[-1 - \frac{2}{N}\cot\theta\cot\frac{\theta}{N} + \frac{1}{N^2}\left(2\cot^2\frac{\theta}{N} + 1\right)\right]$$

The general formula for the radius of curvature of polar curves is

$$r = \frac{\left(\rho^2 + \frac{d\rho^2}{d\theta^2}\right)^{\frac{3}{2}}}{\rho^2 + 2\frac{d\rho^2}{d\theta^2} - \rho\frac{d^2\rho}{d\theta^2}}$$

Substituting in this the values of ρ, $\frac{d\rho}{d\theta}$ and $\frac{d^2\rho}{d\theta^2}$, and putting $\left(\frac{1}{N}\cot\frac{\theta}{N} - \cot\theta\right) = a$, we have after reduction,

$$r = \frac{\rho}{2}\cdot\frac{(1 + a^2)^{\frac{3}{2}}}{1 - \frac{1}{2N^2} - a\cot\theta} \tag{81}$$

This formula being too complicated for convenient use in the field, its use is avoided by referring to Table VII, 2, which contains values of the ratio $\frac{r}{L} = v$ for various values of Δ and L. Multiplying the given value of L by the proper tabular ratio, gives the value of the radius of curvature of the valvoid for a short distance either way from the given point P; or,

$$r = vL \tag{82}$$

149. *To find the* **length of arc** *of the valvoid corresponding to a change of* **one degree** *in the value of the angle* Δ. Fig. 35.

From any chord AP suppose a deflection of $\frac{1}{4}°$ to be made each way to Ap' and Ap''; then the angle $p'Ap'' = \frac{1}{2}°$ = the change in θ, and since $\Delta = 2\theta$, this makes a change of 1° in the value of Δ. We then require to know the length of the arc $p'p''$, and we may, without sensible error, consider it to be described by the radius of curvature $r = Po$ for the point P, through an angle $p'op''$. Now

$$p'op'' = Xop' - Xop'' = \left(\frac{\Delta'}{2} + \phi'\right) - \left(\frac{\Delta''}{2} + \phi''\right) =$$

$$\frac{\Delta'}{2} - \frac{\Delta''}{2} + \phi' - \phi''$$

By eq. (80)

$$\phi' = \frac{\Delta'}{2}(1 - 2u') \quad \text{and} \quad \phi'' = \frac{\Delta''}{2}(1 - 2u'')$$

and since ϕ' is so nearly equal to ϕ'' we may assume $u' = u'' = u$; hence $\phi' - \phi'' = \frac{\Delta' - \Delta''}{2}(1 - 2u)$ and $p'op'' = (\Delta' - \Delta'')(1 - u)$.

But the condition of the problem requires $\Delta' - \Delta'' = 1°$, hence $p'op'' = (1 - u)°$.

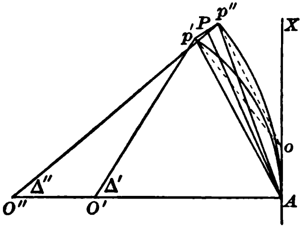

FIG. 35.

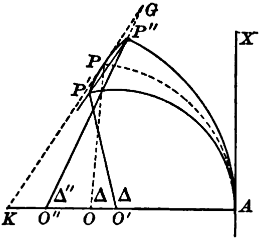

FIG. 36.

Therefore the length of arc $p'p''$ for a change of 1° in the value of Δ is

$$l_1 = r(1 - u) \times \text{arc } 1°$$

or (Table XX) $$l_1 = r(1 - u).0174533$$

and since $r = vL$ (Table VII, 2),

$$l_1 = v(1 - u)L\ .0174533 \tag{83}$$

By this formula Table VII, 3 has been prepared, for various values of Δ and L.

150. *Given:* **two curves** *of the same length L but of different radii, starting from the same point of curve in a common tangent, to determine the* **direction** *and* **length** *of a line* **joining their extremities.** Fig. 36.

Let AX be the common tangent, and AP', AP'' the two curves, to determine the direction and length of $P'P''$.

If we take the point P on the arc P'P'' determined by the angle $\Delta = \frac{\Delta' + \Delta''}{2}$ and draw a tangent PK to the val at P, we may assume without material error that the chord $P'P''$ will be parallel to PK for any value of $P'P''$ not exceeding $\frac{1}{4}L$, a limit not likely to be exceeded in practice.

Let O be the center of the curve AP fixing the point P; then $AOP = \frac{\Delta' + \Delta''}{2}$, and

$$OPK = i = u\frac{\Delta' + \Delta''}{2}$$

$$PKO = K = \frac{\Delta' + \Delta''}{2} - i = \frac{\Delta' + \Delta''}{2}(1 - u)$$

Since $P'P''$ is assumed parallel to PK,

$$P'P''O'' = KGO'' = \Delta'' - K = \Delta'' - \frac{\Delta' + \Delta''}{2}(1 - u)$$

$$\therefore \qquad P'P''O'' = i'' = \frac{\Delta''(1 + u'') - \Delta'(1 - u'')}{2} \tag{84}$$

Similarly producing $P''P'$ to any point H,

$$HP'O' = i' = \frac{\Delta'(1 + u'') - \Delta''(1 - u'')}{2} \tag{85}$$

whence also

$$i' = i'' + \Delta' - \Delta'' \tag{85a}$$

The slight error involved in the above assumption is corrected by taking out the value of u (Table VII, 1) corresponding to Δ'', the *less* of the two given central angles; we have therefore written u with the double accent in eqs. (84) and (85).

When i' and i'' are positive, they will be deflected as in Fig. 36, on the side of the radius *farthest from A*; should i'' be negative it will of course be deflected from $P''O''$ *toward A*.

The arc $P'P''$ corresponds to a change of the central angle from Δ' to Δ''; hence

$$1° : \Delta' - \Delta'' :: l_1 : P'P''$$

or

$$P'P'' = (\Delta' - \Delta'')l_1 \tag{86}$$

in which l_1 is taken from Table VII, 3, for $L = AP$, and $\Delta = \frac{\Delta' + \Delta''}{2}$.

As in practice, the distance $P'P''$ is usually small compared with L, the arc and chord will be almost identical and no further calculation is necessary. If $P'P''$ is large, it will be found that eq. (86) gives the length of *arc* very correctly when $\frac{\Delta' - \Delta''}{2}$ does not exceed 20°, and the length of *chord* when $\frac{\Delta' + \Delta''}{2}$ exceeds 60°; for intermediate mean angles it gives a value to $P'P''$ between that of the arc and chord. The arc $P'P''$ may be considered to be described by the radius $r = vL$, v being taken for $\frac{\Delta' + \Delta''}{2}$ (Table VII, 2), and its total curvature is found by multiplying its length by the degree of curve corresponding to r (Table I).

Example.—Given, a 2° 30′ curve, and a 1° curve of 12 stations each from the same P.C., to determine the distance between their extremities.

$$\Delta' = 2\tfrac{1}{2}° \times 12 = 30°, \qquad \Delta'' = 12°, \qquad \frac{\Delta' + \Delta''}{2} = 21°,$$

$$\Delta' - \Delta'' = 18°, \qquad u'' = .33446$$

Eq. (84). $i'' = 2°.9737 \qquad = 2° \, 58' \, 25''$

Eq. (85*a*). $i' = i'' + \Delta' \times \Delta'' = 20°.9737 = 20° \, 58' \, 25''$

Eq. (86). Arc $P'P'' = 18° \times 10.425 \qquad = 187.65$ ft. *Ans.*

Eq. (82). $r = 1200 \times .7479 = 897.48$ ft. = (say) a $6° \, 23'$ curve.

Total curvature, $P'P'' = 6°.383 \times 1.8765 = 11°.9777$.

(The distance $P'P''$ may be found by solving the triangle formed by itself and the long chords of the curve AP', AP''.)

151. *Given: a curve* **AP,** *to find a curve starting from the same point* **A,** *that shall shift the station* **P** *any desired distance* **PP′** *to the right or left.* Fig. 36.

Before we can determine what distance PP' is desired, we must know (approximately) its direction. We have given, therefore, D, L, and Δ to find the angle OPP', and (after measuring PP') to find Δ' and D'.

The solution is necessarily somewhat approximate, yet close enough *for all* practical purposes. For if the required *value of D' were obtained precisely*, it would probably in volve some seconds, and would therefore be discard favor of some value in even minutes.

When P′ is inside the given curve:

Eq. (80). $i = OPK = u\Delta$. Table VII, 1.

Eq. (82). $r = Po = vL$. Table VII, 2.

Let δ (delta) = degree of curve corresponding to Table I.

$$\therefore \qquad OPP' = i - \frac{PP'}{100}\cdot\tfrac{1}{2}\delta \text{ nearly.}$$

Eq. (86). $\Delta' = \Delta + \dfrac{PP'}{l_1}$. Table VII 3.

Instead of taking l_1 from Table VII, 3, for the exact of Δ it is well to take it for the *estimated* value of $\dfrac{\Delta' + \Delta}{2}$

Eq. (20). $D' = \dfrac{100}{L}\Delta'$

When P′ is outside of the given curve:

$$i = u\Delta, \quad r = vL,$$

$$180° - OPP' = i + \frac{PP'}{100}\cdot\tfrac{1}{2}\delta \text{ nearly.}$$

$$\Delta' = \Delta - \frac{PP'}{l_1}, \quad D' = \frac{100}{L}\Delta'$$

Example.—Given, a 4° curve of 800 feet, or $\Delta = 32°$ find a curve from the same P.C. which shall shift the station, *in*, about 55 feet. (Fig. 36.)

$$i = 32° \times .3355 = 10°.736$$

$$r = 800 \times .7450 = 596, \quad \therefore \ \delta = 9°\,36' = 9°.6$$

$$OPP' = 10°.736 - \frac{55}{100} \times 4°.8 = 8°\,06'$$

$$\Delta' = 32° + \frac{55}{6.87} = 40°$$

$$D' = \frac{40°}{8} = 5°. \quad \textit{Ans.}$$

For a 5° curve, the true distance $PP' = 55.53$
" $4° 59'$ " " " $PP' = 54.60$

which proves this method practically correct.

152. *Given: a tangent and curve, and a* **straight line intersecting** *them, making a given angle with the tangent at a given point, to determine the* **distance on the line** *from the tangent to the curve.* Fig. 37.

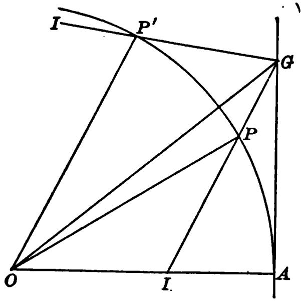

FIG. 37.

We have OA, AG, and the angle AGP to find GP.

$$\tan AGO = \frac{R}{AG} \qquad PGO = AGO - AGP$$

$$\sin OPI = \frac{OG}{R} \sin PGO = \frac{\sin PGO}{\sin AGO}$$

$$PG = R\frac{\sin (OPI - PGO)}{\sin PGO}$$

When $AGP = AGO$, eq. (24),

$$GP = R \operatorname{ex\,sec} (90° - AGO)$$

When $AGP = 90°$, §§ (92), (119),

$$GP = R \operatorname{vers} POA, \qquad \sin POA = \frac{GA}{R}$$

When $AGP' > AGO$, we have

$$P'GO = AGP' - AGO$$

but the other formulas remain unchanged.

Example.—Let $R = 955.37$, $AG = 350$, $AGP = 40°$.

Ans. $AGO = 69° 52' 47''$, $OPI = 32° 02' 36''$ and $GP = 72.40$.

This problem may be used in passing from a tangent to a curve when the tangent point is obstructed. The distance AP on the curve is defined by the angle AOP, which is readily found.

If $AGP' > 2AGO$ the line will not cut the curve.

Approximate Method. The point P may be located by "string intersection" which amounts to placing two stakes on the line GI (one each side of P) and finding by trial, the point where the curve cuts a string connecting the two stakes.

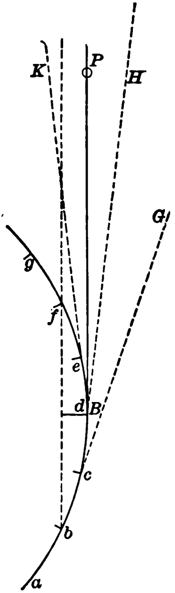

Fig. 38.

Remark. If G is considered the V of the curve and the distance GP and angle AGP are measured, the radius of a curve which will pass through the point P may be found by first solving the equation for angle OPI and then the one which follows for R. The problem will then be a modification of that in § 144.

153. *Given: a curve and a* **distant point** *to find a* **tangent** *that shall pass* **through the point.** Fig. 38.

We have the curve adg and the point P visible, but distance unknown, to find the point of tangent B.

First Method. Any chord, as bf, parallel to the required tangent, if produced will pass the point P at a perpendicular distance equal to the middle-ordinate of that chord. Ranging across every two consecutive stakes on the curve we at first find the range falling outside of the required tangent, as [illegible] cdH, etc.; but finally the range falls inside, as deK. [illegible] then know that the required point is between c and e. [illegible] *range ce* falls inside the point P, a perpendicular [illegible]*ce equal to* the middle-ordinate of ce, the tangent point is at d. If the perpendicular distance is greater than this, the point B is between c and d. If less, or if the range ce falls outside of P, the point B is between d and e. The middle-ordinate for ce (200 feet) equals the tangent offset for 100 feet, given in Table I, and it is generally so small that it can be estimated at P without going to lay it off.

To find the exact point B, when it falls between d and e, find by trial a point x (not shown) on the arc cd in range with e and a point inside of P a perpendicular distance equal to the middle-ordinate of ex. The point B is at the middle point of the arc ex. If the point B is between c and d, stand at c and find a point x on the arc de in the same way. B is at one half the arc cx.

The middle-ordinate of any chord ex is less than M for 200 feet, and greater than m for 100 feet. If necessary, its exact value m' can be found by

$$m' = \frac{m \times \overline{ex}^2}{10{,}000} \tag{87}$$

and this equation is nearly true when ex is as great as 300 or 400 feet. That is, middle-ordinates on the same curve are to each other as the squares of their chords *very nearly*.

By this method the point B is found without the use of the transit, so that the plug can be driven at B before the transit is brought up from the rear. It is therefore preferable to the following solution.

Second Method. Fig. 39. From any two points a and c of the curve measure the angles to the point P, so that with the chord ac as a base, and the measured angles, we may find cP by the formula

$$cP = ac\frac{\sin caP}{\sin cPa}$$

Knowing the angle c that cP makes with a tangent at c, we find the length of the chord cd by $cd = 2R \sin c$.

By Geom. Table XLI, 24,

$$PB = Pe = \sqrt{cP \times dP}$$

whence we know ce. Opposite e, or on the arc eB described *with the radius Pe,* we find B.

154. *Given: two curves exterior to each other, to find the tangent points of a line tangent to both and its length between tangent points.* Fig. 40.

Let B and A be the required tangent points. Let $OB = R$, and $O'A = R'$.

On the curve of greater radius R select a point H supposed to be near the unknown tangent point B, and knowing the direction of the radius OH, find on the other curve a point K having a radius $O'K$ parallel to OH, and measure HK.

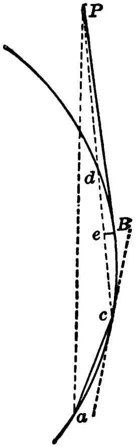

FIG. 39.

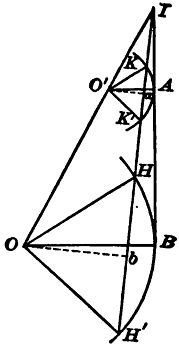

FIG. 40.

In the diagram draw Ob and $O'a$ perpendicular to HK. Then the angle $KO'a = 90° - HKO' = KO'A$ nearly, which is the angle required. We have therefore to find the correction $aO'A = x$, and apply it to $KO'a$.

$$Aa = R' \text{ vers } KO'a; \qquad Bb = R \text{ vers } KO'a \text{ nearly.}$$

$$Ka = R' \sin KO'a; \qquad Hb = R \sin KO'a$$

$$\therefore \quad Bb - Aa = (R - R') \text{ vers } KO'a$$

$$ab = HK + (R - R') \sin KO'a$$

$$\therefore \quad \sin x = \frac{(R - R') \text{ vers } KO'a}{HK + (R - R') \sin KO'a} \text{ nearly.} \qquad (88)$$

$$KO'A = (KO'a - x) = HOB$$

Observe that $KO'a$ = the angle between the tangent at K or H and the line HK; and $KO'A$ = the angle between the tangent at K or H and the required tangent BA.

If, instead of H and K, the points H' and K' had been selected, then

$$\sin x = \frac{(R - R') \text{ vers } H'Ob}{H'K' - (R - R') \sin H'Ob} \text{ nearly,} \qquad (88a)$$

and

$$H'OB = K'O'A = H'Ob + x.$$

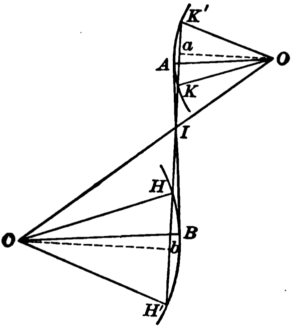

FIG. 41.

The length of BA should be obtained by measurement, but it may be calculated by

$$AB = ab - (R - R') \sin x \qquad (89)$$

When $R = R'$, $x = 0$, and HK is parallel to BA.

In case the **curves** *are* **reverse** *to each other, as in Fig.* 41,

$$\sin x = \frac{(R+R') \text{ vers } KO'a}{HK+(R+R') \sin KO'a} \text{ nearly.} \qquad (90)$$

$$KO'A = HOB = KO'a - x$$

If the points H' and K' are selected, Fig. 41,

$$\sin x = \frac{(R + R') \text{ vers } H'Ob}{H'K' - (R + R') \sin H'Ob} \text{ nearly.} \qquad (91)$$

$$H'OB = K'O'A = H'Ob + x.$$

The lines HK, AB, and OO' all intersect in a common point I, Fig. 41.

$$HI = \frac{HK \times R}{R + R'} \tag{92}$$

$$IB = \sqrt{HI(HI + 2R \sin HOb)} \tag{93}$$

$$AB = IB\frac{R + R'}{R} \tag{94}$$

These last three equations furnish **another method** of solving the same problem. They may be applied to Fig. 40 by changing the sign of R'.

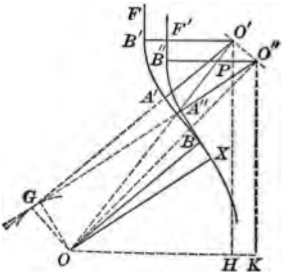

FIG. 42.

In Fig. 41, if $R = R'$, then $HI = \frac{1}{2}HK$ and $AB = 2IB$.

155. *Given:* **two curves, O and O', reverse** *to each other, joined by a tangent* **BA'**, *and terminating in another tangent,* **B'F; to change** *the position of the* **Point of Tangent B** *of the first curve, so that the second curve may terminate in a given* **parallel tangent, B''F'. Fig. 42.**

Let X be the required new position of B;

O'' be the corresponding position of O';

$\Delta' = A'O'B'$ and $\Delta'' = A''O''B''$.

Since the radii and the connecting tangent are unchanged in length, and all rotate together about O as a center, O'' will be on a circle passing through O', described with a radius OO', and the required angle $BOX = O'OO''$.

In the diagram, produce $O'A'$ and draw the perpendicular OG, *and let* α = the angle $OO'G$. Also, draw OK parallel and $O''K$ and $O'H$ perpendicular to $B'O'$. In the triangle $OO'G$ we have

$$\cot OO'G = \frac{GO'}{GO}, \quad \text{or} \quad \cot \alpha = \frac{R + R'}{BA'} \tag{95}$$

and

$$OO' = \frac{R + R'}{\cos \alpha} \tag{96}$$

The angle $KOO' = OO'B' = \alpha + \Delta'$.

The angle $KOO'' = OO''B'' = \alpha + \Delta''$.

$$KO = OO'' \cdot \cos (\alpha + \Delta''), \quad HO = OO' \cos (\alpha + \Delta').$$

$$\therefore \quad HK = OO' [\cos (\alpha + \Delta'') - \cos (\alpha + \Delta')] = B'F'$$

$$\therefore \quad \cos (\alpha + \Delta'') = \cos (\alpha + \Delta') + \frac{B'F'}{OO'} \tag{97}$$

$$BOX = O'OO'' = (\alpha + \Delta') - (\alpha + \Delta'') \tag{98}$$

If we conceive a line to be drawn through O bisecting the arc $O'O''$, the angle it makes with $B''O''$ is a mean between $B'O'O$ and $B''O''O$; hence the chord $O'O''$, perpendicular to this line, makes an angle with $O'P$ perpendicular to $B'O'$ of

$$PO'O'' = \tfrac{1}{2}[(\alpha + \Delta') + (\alpha + \Delta'')]$$

and since

$$O'P = PO'' \cot PO'O''$$

$$F'B'' = B'F' \cot \tfrac{1}{2}[(\alpha + \Delta') + (a + \Delta'')] \tag{99}$$

which gives the distance, measured on the parallel tangent, between the old tangent point and the new.

This problem occurs in practice when both the connecting tangent and the radius of the last curve are at their *minimum limit,* and the parallel tangent is *inside* of the old one, as in the figure. Should the new tangent be *outside,* the same formulas apply, only changing the sign of $B'F'$ in eq. (97). But in this last case it is usually preferable to employ problem § 136 or § 137.

Example.—A 1° 40′ curve is followed by a tangent of 200 feet, and that by a 4° curve of 10 stations ending in a tangent; and the offset to the given parallel tangent is 80 feet on the inside. *Required,* the position of the new tangent *points X and B''.*

Here $R = 3437.87, R' = 1432.69, BA' = 200, B'F' = 80.$

Eq. (95)	$R + R'$	4870.56		log 3.687579
	BA'	200.		log 2.301030
∴	α	2° 21′		log cot 1.386549
Eq. (96)	α	2° 21′		log cos 9.999635
∴	OO'			3.687944
Eq. (97)	$B'F'$	80		1.903090
			.01641	8.215146
	$\alpha + \Delta'$	42° 21′ cos	.73904	
	$\alpha + \Delta''$	40° 56′ cos	.75545	

Eq. (98) BOX 1° 25′ ∴ $BX = 85$ ft. *Ans.*

Eq. (99) $PO'O''$ 41° 38′ 30″ cot $1.12468 \times 80 = 89.97 = F'B'$

156. When the tangents of a proposed road are to be in general much longer than the curves, it is desirable to establish the tangents first in making the location, and afterwards determine suitable curves. On the other hand, if the curves necessarily predominate, they should be first selected and adjusted to the ground with reference to grade and easy alinement, and afterwards joined by tangents. In the latter case the field work cannot be successfully accomplished unless the location has been previously worked out upon a correct map constructed from the preliminary surveys. The map should show contours of the surface, and also the grade contour, or intersection of the surface and plane of the grade. In side-hill work the grade contour indicates approximately the degree and position of the necessary curves. In the work of selecting proper curves upon the map, **templets** or pattern curves are almost indispensable.

Pattern curves are furnished by dealers in sets of twenty, representing as many curves in series ranging from 1° up and cut to a scale of 50 feet to the inch, or of 100 feet to the inch; also in series ranging from 0° 30′ up, cut to a scale of 400 feet to the inch. These apply fairly well to maps drawn to other scales by making proper correction. Thus, the 4° templet of 100 feet to the inch may be used as a 2° *curve upon a* map drawn 200 feet to the inch, or as a 1° *curve upon a* map of 400 feet to the inch.

s of 50 minutes and multiples of 50 minutes are most nt in the field for making the necessary deflections points between stations by reason of the simple minutes to feet; but such templets are not furnished trade. They may be cut in the office from Bristol y means of a sharp knife point set in one socket of compass. Scale and degree should be marked on

TABLE OF CONVENIENT CURVES

Ratio of Min. to Feet.	D.	Ratio of Min. to Feet.	D.	Ratio of Min. to Feet.
1 : 2	40′	2 : 5	30′	3 : 10
1 : 1	1° 20′	4 : 5	1° 00′	3 : 5
3 : 2	2° 00′	6 : 5	1° 30′	9 : 10
2 : 1	2° 40′	8 : 5	2° 00′	6 : 5
5 : 2	3° 20′	2 : 1	2° 30′	3 : 2
3 : 1	4° 00′	12 : 5	3° 00′	9 : 5
7 : 2	4° 40′	14 : 5	3° 30′	21 : 10
4 : 1	5° 20′	16 : 5	4° 00′	12 : 5
9 : 2	6° 00′	18 : 5	4° 30′	27 : 10
5 : 1	6° 40′	4 : 1	5° 00′	3 : 1
11 : 2	7° 20′	22 : 5	5° 30′	33 : 10
6 : 1	8° 00′	24 : 5	6° 00′	18 : 5

Location. After the curves and tangents have been out upon the preliminary map in pencil the line be stationed with stepping dividers set precisely scale of the map (which may have shrunk slightly), them on a stretch of, say twenty stations. The etween tangent lines are now determined, tangent s computed and laid off to scale, fixing each P.C. ., recording the plus on the map, and the bearing of gent. Notes for use in the field are taken from the ith memoranda of crossing points and prominent by which to correct in the field any discrepancies ay arise. (See § 54.) If the work has been well ese notes may be followed in the field with scarcely rations, and the tangents need not be extended to tersections in many instances. But with a poor or ete map the line to be located may be only roughly d on the *map,* leaving the actual location to be *out on the* ground at a greatly increased expens of time, not to mention the necessity for further revision in some places.

In difficult country a trial profile may be read off from the contours of a good map, and certain revisions of the pencil line may be made before going into the field with a locating party. This precaution is of great importance when the line is to be laid to the maximum limit of grade.

CHAPTER VI

COMPOUND CURVES

A. Theory

157. A compound curve consists of two or more consecutive circular arcs of different radii, having their centers on the same side of the curve; but any two consecutive arcs must have a common tangent at their meeting point, or their radii at this point must coincide in direction. The meeting point is called the point of compound curve, or P.C.C. *Compound curves are employed to bring the line of the road upon more favorable ground than could be done by the use of any simple curve.*

When a compound curve of two arcs connects two tangent lines, the tangent points are at unequal distances from the intersection or vertex, the shorter distance being on the line which is tangent to the arc of shorter radius.

158. Let VA, VB (Fig. 43) be any two right lines intersecting at V, and Δ be the deflection angle between them. Let A and B be the tangent points of a compound curve (VA less than VB), and let AP, PB be the two arcs of the curve. The center O_1 of the arc AP will be found on AS, drawn perpendicular to VA; the center O_2 of the arc PB will be found on BS produced perpendicular to VB; and the angle ASB will evidently equal Δ. Join VS, and on VS as a diameter describe a circle; it will pass through the points A and B, since the angles VAS, VBS are right angles in a semicircle. Draw the chord VQ, bisecting the angle AVB, and join AQ, BQ. Then AQ, BQ are equal, since they are chords subtending the equal angles AVQ, BVQ. From Q as a center, and with radius QA, describe a circle; it will cut the tangent lines at A and B, and also at two other points G and Y, such that $VG = VA$, and $VY = VB$. Hence $BG = AY$, and the parallel chords AG, BY are perpendicular to VQ. Join AB; then $AQB = ASB = \Delta$, since both angles are subtended by the same chord AB.

In the triangle VAB, the sum of the angles at A and B is equal to the exterior angle Δ between the tangents; while their difference $(A - B)$ is equal to the angle at the center Q subtended by the chord BG, which is the difference of the sides $(VB - VA)$. For the angle $VAB = VAG + GAB$, and the angle $VBA = VBY - ABY$. But $VAG = VBY$ and $GAB = ABY$, and by subtraction $VAB - VBA = 2GAB = GQB$, since A is on the circumference and Q at the center.

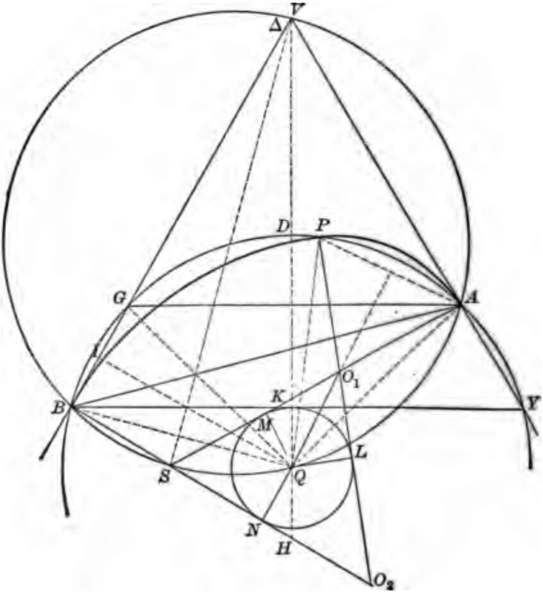

Fig. 43.

159. Theorem.—*The circle YAGB, whose center is Q, is the* locus *of the point of compound curve P, whatever be the relative lengths of the* arcs *AP, PB* composing the curve.

On the circle $YAGB$, and between A and G, take any point P, and on AS find a center O_1, from which a circular arc may be drawn cutting the circle at A and P; also on BS produced find a center O_2, from which a circular arc may be drawn cutting the circle at B and P. Join PQ, PO_1 and PO_2. Since when two circles intersect, the angles are equal between radii drawn to the points of intersection, $QPO_1 = QAO_1$ and $QPO_2 = QBO_2$. Draw the chord QS and it subtends the equal angles $QAO_1 = QBO_2$. Hence $QPO_1 = QPO_2$ and the radius PO_1 coincides in direction with the radius PO_2, which is the condition essential to a compound curve.

Now, if we imagine another point P' to be taken on QP or on QP produced, and the arcs AP' BP', drawn from centers found on AS and BS, it is evident that the equality of angles found in respect to P could not exist in respect to P'. Hence the arcs would intersect in P' at some angle O_1PO_2 and would not form a compound curve. Therefore, Q. E. D.

160. THEOREM.—*In any compound curve the radial lines passing through the three tangent points A, P, and B are all tangent to a circle having the point Q for its center, and for its diameter the difference of the sides VB and VA.*

Draw the three lines QN, QL, QM perpendicular to the radial lines BO_2, PO_2, and AS respectively. Then the three right-angled triangles BQN, PQL, and AQM are equal, since $BQ = PQ = AQ =$ radius of the circle AGB, and the angles at B, P, and A are equal by the last theorem. Hence $QM = QL = QN$; and if a circle be described with this radius about Q, the three lines BO_2, PO_2, and AO_1 produced will be tangent to it. Draw QI perpendicular to VB; it will bisect the chord GB in I; and $QN = BI = \frac{1}{2}BG$. Hence the diameter $2QN = BG = VB - VA$; which was to be proved.

Corollary 1. The compound curve intersects the circle AGB in the point P, at an angle equal to half the difference of the angles VAB, VBA. For $QPL = QBN = BQI = \frac{1}{2}BQG$. The arc AP is exterior, and the arc PB interior to the circle AGB.

Cor. 2. Since both centers are on the line PL, the position of the point P fixes the lengths of the radii of a compound curve. As P is moved toward G both radii are increased.

until when P reaches G, AO_1 becomes AK, a *max* while BO_2 becomes infinite. As P moves toward A radii are diminished, but the least value of the arc AP de upon the least radius allowed on the road. If in the di we make AO_1 equal to the least radius allowed, a righ drawn through the point O_1 tangent to the circle fixes the corresponding *minimum* value of the arc A also of the radius BO_2 for given values of VA, VB, a Between these limits any desired values of the radii be employed.

Cor. 3. In the triangle SO_1O_2, the sum of the two c angles AO_1P and PO_2B is equal to the exterior angle ASB consequently, as the central angle of one arc is incr by any change in the position of the point P, the c angle of the other will be diminished an *equal amount.*

Cor. 4. Only one value of the angle AO_1P is cons with a given value of the radius AO_1, since both d on the variable position of the line PL; and for the reason only one value of the angle BO_2P is consistent a given value of the radius BO_2. *Hence only one r or one central angle can be assumed at pleasure, the remo parts being deducible therefrom in terms of the sides VA and the angle Δ.*

B. General Equations

161. Let S_1 = the side VA = the shorter tangent;
S_2 = the side VB = the longer tangent;
R_1 = the radius AO_1;
R_2 = the radius BO_2;
γ = diff. $VAB - VBA$;
Δ = the sum $VAB + VBA$;
Δ_1 = central angle AO_1P;
Δ_2 = central angle BO_2P.

In the triangle BQI, $\cot BQI = \frac{IQ}{BI}$. But $IQ =$ cot $IQV = \frac{1}{2}(S_2 + S_1) \cot \frac{1}{2}\Delta$, and $BI = \frac{1}{2}(S_2 - S_1)$.

$$\therefore \qquad \cot \tfrac{1}{2}\gamma = \frac{S_2 + S_1}{S_2 - S_1} \cot \tfrac{1}{2}\Delta$$

By Cor. 3,

$$\Delta_1 + \Delta_2 = \Delta$$

the triangle AQM, $AO_1 = AM - MO_1$. But $AM =$ ot $\frac{1}{2}\gamma$, and $MO_1 = MQ \cot \frac{1}{2}\Delta_1$.
w $MQ = \frac{1}{2}(S_2 - S_1)$

$$\left.\begin{aligned} R_1 &= \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\gamma - \cot \tfrac{1}{2}\Delta_1) \\ R_2 &= \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\gamma + \cot \tfrac{1}{2}\Delta_2) \end{aligned}\right\} \tag{102}$$

rly,

acting,

$$R_2 - R_1 = \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\Delta_2 + \cot \tfrac{1}{2}\Delta_1) \tag{103}$$

om (102),

$$\left.\begin{aligned} \cot \tfrac{1}{2}\Delta_1 &= \cot \tfrac{1}{2}\gamma - \frac{R_1}{\tfrac{1}{2}(S_2 - S_1)} \\ \cot \tfrac{1}{2}\Delta_2 &= \frac{R_2}{\tfrac{1}{2}(S_2 - S_1)} - \cot \tfrac{1}{2}\gamma \end{aligned}\right\} \tag{104}$$

triangle ABG,

$$BG = \frac{AB \sin BAG}{\sin AGV}$$

$$\tfrac{1}{2}(S_2 - S_1) = \frac{\tfrac{1}{2}AB \sin \tfrac{1}{2}\gamma}{\sin \tfrac{1}{2}\Delta} \tag{105}$$

ich we find $\frac{1}{2}(S_2 - S_1)$, when, instead of the sides and have given AB, and the angles VAB and VBA.

m (103),

$$\tfrac{1}{2}(S_2 - S_1) = \frac{R_2 - R_1}{\cot \tfrac{1}{2}\Delta_2 + \cot \tfrac{1}{2}\Delta_1} \tag{106}$$

m (102),

$$\left.\begin{aligned} \cot \tfrac{1}{2}\gamma &= \frac{R_1}{\tfrac{1}{2}(S_2 - S_1)} + \cot \tfrac{1}{2}\Delta_1 \\ \cot \tfrac{1}{2}\gamma &= \frac{R_2}{\tfrac{1}{2}(S_2 - S_1)} - \cot \tfrac{1}{2}\Delta_2 \end{aligned}\right\} \tag{107}$$

m (100),

$$\tfrac{1}{2}(S_2 + S_1) = \frac{\tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\gamma}{\cot \tfrac{1}{2}\Delta} \tag{108}$$

d S_1 are found by adding and subtracting the values ed by eqs. (106), (108).

m (105),

$$\tfrac{1}{2}AB = \frac{\tfrac{1}{2}(S_2 - S_1) \sin \tfrac{1}{2}\Delta}{\sin \tfrac{1}{2}\gamma} \tag{109}$$

may be used *instead* of (108) when the sides are not *ed.* $VAB = \frac{1}{2}(\Delta + \gamma)$ and $VBA = \frac{1}{2}(\Delta - \gamma)$.

162. *Given: the sides $VA = S_1$ and $VB = S_2$ and the angle Δ; assuming the shorter radius R_1,* **to find** Δ_1, Δ_2 and R_2.

Use eqs. (100), (104,) (101), (102), and (18).

Example.—Let $VB = 1899.90$, $VA = 1091.12$, $\Delta = 74°$, and assume $R_1 = 955.37$.

(100)	$\frac{1}{2}(S_2 + S_1)$	1495.51		log 3.174789
	$\frac{1}{2}(S_2 - S_1)$	404.39		" 2.606800
				" 0.567989
	$\frac{1}{2}\Delta$	37°		cot " 0.122886
∴	$\frac{1}{2}\gamma$	11° 31′ 01″.5	cot 4.90769 "	" 0.690875
(104)	$R_1(D = 6°)$			" 2.980170
	$\frac{1}{2}(S_2 - S_1)$			" 2.606800
			2.36249	" 0.373370
∴	$\frac{1}{2}\Delta_1$	21° 27′	cot 2.54520	
(101)	$\frac{1}{2}\Delta$	37°		
∴	$\frac{1}{2}\Delta_2$	15° 33′	" 3.59370	
(102)	$\frac{1}{2}\gamma$		" 4.90769	
			8.50139	" 0.929490
	$\frac{1}{2}(S_2 - S_1)$			" 2.606800
∴	$R_2(D = 1° 40')$			3.536290

(18) ∴ $\Delta_1 = 42°54'$, $L_1 = 715$; $\Delta_2 = 31° 06'$, $L_2 = 1866$.

163. *Given: the line AB, and the angles VAB, VBA; assuming the longer radius R_2,* **to find** Δ_2, Δ_1, *and* R_1.

Example.—Let $AB = 2437.82$, $VAB = 48° 31'$, $VBA = 25° 29'$, and assume $R_2 = 3437.87$.

Use eqs. (105), (104), (101), and (102).

Ans. $\frac{1}{2}(S_2 - S_1) = 404.38$; $\frac{1}{2}\Delta_2 = 15° 33'$; $\frac{1}{2}\Delta_1 = 21° 27'$; and $\log R_1 = 2.980192$ with $D = 6°$.

164. Usually a compound curve is fitted by trial to the shape of the ground, after which it may be desirable to **calculate** the sides *VA*, *VB*, or the line *AB*, and the angles *VAB*, *VBA*.

Example.—From the point of curve *A*, a 6° curve is run *715 feet to the* P.C.C.; thence a 1° 40′ curve is run 1866 feet to the P.T. *Required*, the sides VA, VB, and the line AB, and angles VAB, VBA. Here $R_1 = 955.37$, $\Delta_1 = 42° 54'$. $R_2 = 3437.87$, $\Delta_2 = 31° 06'$.

Use eqs. (106), (107), (108), and (109).

Ans. $S_2 = 1899.90$; $S_1 = 1091.12$; $VAB = 48° 31'$; $VBA = 25° 29'$; and $AB = 2437.82$.

165. *Given the radii* R_1, R_2, *the angle* Δ, *and one side,* VA, *or* VB, **to find** *the other side and the central angles* Δ_1, Δ_2. Fig. 43.

In the triangle AMQ, $AO_1 = AM - MO_1 = IQ - MQ \cot MO_1Q$; or

$$R_1 = \tfrac{1}{2}(S_2 + S_1) \cot \tfrac{1}{2}\Delta - \tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\Delta_1$$

whence

$$\tfrac{1}{2}(S_2 + S_1) = \tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\Delta_1 \tan \tfrac{1}{2}\Delta + R_1 \tan \tfrac{1}{2}\Delta$$

By eq. (106),

$$\tfrac{1}{2}(S_2 - S_1) = (R_2 - R_1) \frac{\sin \tfrac{1}{2}\Delta_2 \sin \tfrac{1}{2}\Delta_1}{\sin \tfrac{1}{2}\Delta}$$

Substituting this above, subtracting and reducing

$$S_1 = (R_2 - R_1) \sin \tfrac{1}{2}\Delta_2 \frac{\sin \tfrac{1}{2}(\Delta - \Delta_1)}{\tfrac{1}{2}\sin \Delta} + R_1 \tan \tfrac{1}{2}\Delta$$

But $\tfrac{1}{2}(\Delta - \Delta_1) = \tfrac{1}{2}\Delta_2$ and $2 \sin^2 \tfrac{1}{2}\Delta_2 = \text{vers } \Delta_2$, whence

$$S_1 = \frac{(R_2 - R_1) \text{ vers } \Delta_2 + R_1 \text{ vers } \Delta}{\sin \Delta} \tag{110}$$

Transposing,

$$\text{vers } \Delta_2 = \frac{S_1 \sin \Delta - R_1 \text{ vers } \Delta}{R_2 - R_1} \tag{111}$$

Similarly, from the triangle BQO_2,

$$R_2 = \tfrac{1}{2}(S_2 + S_1) \cot \tfrac{1}{2}\Delta + \tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\Delta_2$$

from which and eq. (106) we derive

$$S_2 = \frac{R_2 \text{ vers } \Delta - (R_2 - R_1) \text{ vers } \Delta_1}{\sin \Delta} \tag{112}$$

and

$$\text{vers } \Delta_1 = \frac{R_2 \text{ vers } \Delta - S_2 \sin \Delta}{R_2 - R_1} \tag{113}$$

Example.—*Given:* $VA = S_1 = 1091.12$, $\Delta = 74°$, and the *radii* $R_1 = 955.37$, $R_2 = 3437.87$, to find Δ_1, Δ_2, and S_2.

Use eqs. (111), and (112).

Ans. $\Delta_2 = 31° 06'$; $\Delta_1 = 42° 54'$; $S_2 = 1899.90$.

166. *Given one side, and the radius and central angle of the adjacent arc,* **to find** *the other radius and side.*

From eqs. (111), (113) we have

$$\left.\begin{aligned} R_2 - R_1 &= \frac{S_1 \sin \Delta - R_1 \operatorname{vers} \Delta}{\operatorname{vers} \Delta_2} \\ R_2 - R_1 &= \frac{R_2 \operatorname{vers} \Delta - S_2 \sin \Delta}{\operatorname{vers} \Delta_1} \end{aligned}\right\} \qquad (114)$$

by one of which the required radius may be found; the required side is then found by eq. (110) or (112), as in the last problem.

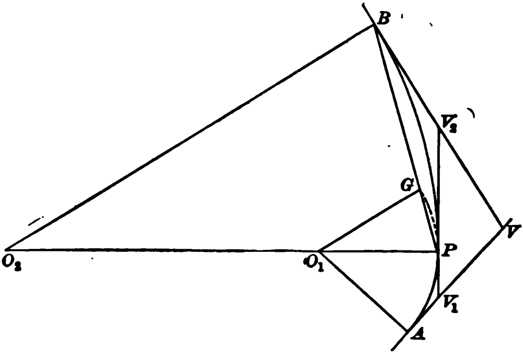

Fig. 44.

Example.—Given: $VA = S_1 = 1091.12$, $\Delta = 74°$, $R_1 = 955.37$ and $\Delta_1 = 42° 54'$; to find R_2. $\Delta_2 = 74° - 42° 54' = 31° 06'$.

Use eq. (114) and (112).

Ans. $R_1 - R_2 = 2482.52$; $R_2 = 3437.89$.

Otherwise: Fig. 44. If convenient in the field, a tangent PV_2 may be run from the point P to intersect the farther tangent. The distance PV_2 multiplied by $\cot \frac{1}{2}\Delta_2$ will equal the radius R_2 by eq. (25).

167. *Remarks.*—If the first arc AP be produced to G, Fig. 44, so that $AO_1G = \Delta$, then G is the tangent point of a tangent parallel to VB, and by § 137, the tangent point B must be on the line PG produced. Conversely, if the point B is assumed, and the arc AG given, the point P must be on the line BG produced. The radius R_2 may be found by $R_2 = \frac{BP}{2 \sin \frac{1}{2}\Delta_2}$, BP being measured on the ground; or by similar triangles $R_2 : R_1 :: BP : GP$.

The distance VD, Fig. 43, from the vertex to the circle AGB is expressed by the formula

$$VD = S_1 \cos \frac{\Delta}{2}\left(\tan \frac{\Delta}{2} - \tan \frac{\Delta - \gamma}{4}\right) \tag{115}$$

If the point P falls at D, then VD is also the distance of the curve from the vertex measured on the line VQ. But when P falls at D, the radius PO_2 is perpendicular to the line AB, and $\Delta_1 = VAB$, and $\Delta_2 = VBA$. When Δ_1 is greater than VAB, the arc AP, being exterior to the circle, cuts the line VD; but when Δ_1 is less than VAB, the arc PB cuts the line DQ.

If the line O_2P produced passes through V, we have

$$\sin QVL = \frac{S_2 - S_1}{S_2 + S_1} \sin \tfrac{1}{2}\Delta \tag{116}$$

giving $\Delta_1 = \frac{1}{2}\Delta + QVL$ and $\Delta_2 = \frac{1}{2}\Delta - QVL$.

When Δ_1 is *greater* than this, we have for the external distance of the vertex

$$E_1 = R_1 \text{ ex sec } AO_1V$$

in which the angle AO_1V is found by the formula $\cot AO_1V = \frac{R_1}{S_1}$, and E_1 is measured on a line VO_1, making the angle $AVO_1 = 90° - AO_1V$.

When Δ_1 is less than $(\frac{1}{2}\Delta + QVL)$, we have similar expressions with respect to the arc BP and center O_2.

168. *To locate a compound curve when the point of compound curve is inaccessible.* Fig. 45.

Each arc being in itself a simple curve is located as such. When the P.C.C. is accessible, the transit is placed over it, and the direction of the common tangent found, from which the second arc is then located.

When the P.C.C. *is not* accessible, the common tangent V_1V_2 *may be found* by locating the points V_1 and V_2 which may be easily done, since $V_1A = V_1P = R_1 \tan \frac{1}{2}\Delta_1$, and $V_2B = V_2P = R_2 \tan \frac{1}{2}\Delta_2$, from which each arc may then be located by offsets or otherwise, as in the case of simple curves.

Should the points $V_1 V_2$ be obstructed, the common tangent may be found by an offset $HG = LP$ from any convenient point H, for knowing the angle HO_1P, we have $HG = R_1$ vers HO_1P, and $GP = R_1 \sin HO_1P$.

If the entire tangent V_1V_2 is too much obstructed for use, the parallel line HK may be employed, observing that the angle PO_2K is found by vers $PO_2K = \frac{LP}{R_2}$, and the distance LK by $LK = R_2 \sin PO_2K$, by which a point K on the second arc is found having a tangent offset $KI = HG$.

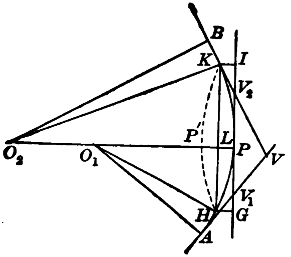

Fig 45.

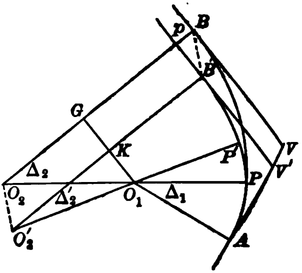

Fig. 46.

Should the line HK be also obstructed, we may run the inverted curve $HP' = HP$ and $P'K = PK$ to find the point K from which so much of the second arc as is accessible may be located.

C. Special Problems in Compound Curves

169. *Given: a compound curve ending in a tangent; to* **change** *the* **P.C.C.** *so that the curve may end in a given* **parallel tangent.** Fig. 46.

Let APB be the given curve ending in VB;

$V'B'$ be the given parallel tangent;

p = perpendicular distance between tangents.

It is required to change the point P, and with it the values of Δ_1 and Δ_2, so that with the same radii R_1 and R_2 the new curve $AP'B'$ may end in the parallel tangent $V'B'$.

a. *When the tangent $V'B'$ is* **inside** *of VB:*

Let $\Delta_1 = AO_1P$, $\Delta_1' = AO_1P'$, $\Delta_2 = PO_2B$, $\Delta_2' = P'O_2'B'$, and in the diagram draw O_1G perpendicular to BO_2; then $GO_2 = O_1O_2 \cos \Delta_2$, $KO_2' = O_1O_2' \cos \Delta_2'$. Subtracting, since $O_1O_2 = O_1O_2' = (R_2 - R_1)$, and $KO_2' - GO_2 = GB - KB' = p$,

$$p = (R_2 - R_1)(\cos \Delta_2' - \cos \Delta_2)$$

whence

$$\cos \Delta_2' = \frac{p}{R_2 - R_1} + \cos \Delta_2 \tag{117}$$

$PO_1P' = (\Delta_2 - \Delta_2')$ and the point P is *advanced.*

b. *When the tangent $V'B'$ is* **outside** *of VB:*

$$p = (R_2 - R_1)(\cos \Delta_2 - \cos \Delta_2')$$

whence

$$\cos \Delta_2' = \cos \Delta_2 - \frac{p}{R_2 - R_1} \tag{118}$$

$PO_1P' = (\Delta_2' - \Delta_2)$ and the point P is *moved back* and the arc AP diminished.

In case the curve **terminates with** *the arc of* **shorter radius,** *or R_1 follows R_2.* Fig. 47.

c. When $V'B'$ is **inside** *of VB:*

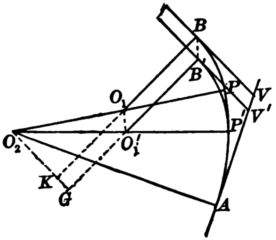

FIG. 47.

$$p = (R_2 - R_1)(\cos \Delta_1 - \cos \Delta_1')$$

whence

$$\cos \Delta_1' = \cos \Delta_1 - \frac{p}{R_2 - R_1} \tag{119}$$

$PO_2P' = (\Delta_1' - \Delta_1)$ and the point P is *moved back.*

d. *When $V'B'$ is* **outside** *of VB:*

$$p = (R_2 - R_1)(\cos \Delta_1' - \cos \Delta_1)$$

whence

$$\cos \Delta_1' = \cos \Delta_1 + \frac{p}{R_2 - R_1} \tag{120}$$

$PO_2P' = (\Delta_1 - \Delta_1')$ and the point P is *advanced.*

Example.—*Let* $R_2 = 2292.01$, $R_1 = 1432.69$, $\Delta_2 = 28°$, and $p = 20.07$ inside of VB; case **a.**

	p	20.07				log	1.302547
(117)	$R_2 - R_1$	859.32				"	2.934155
					.023356	"	8.368392
	Δ_2		28°	cos	.88295		
∴	Δ'_2		25°	"	.906306		
∴	PO_1P'		3°				

170. *Given: a compound curve terminating in a tangent,* **to change** *the* **P.C.C.** *and also the* **last radius,** *so that the curve shall end in a* **parallel tangent** *at a point on the* **same radial line** *as before.* Fig. 48.

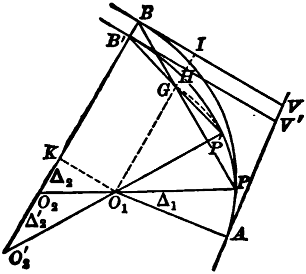

FIG. 48.

Let APB be the given curve ending in the tangent VB; let $V'B'$ be the given parallel tangent; and let $p = BB' = HI$ = the perpendicular distance between tangents.

It is required to change the point P to P', and also the value of R_2 to R_2', so that the new curve may end in $V'B'$ at B' **inside** of VB on the same radial line BO_2.

In the diagram produce the arc AP to G to meet O_1G drawn parallel to O_2B; then $PO_1G = \Delta_2$. Draw the chord PB, and it will pass through G. Lay off the distance p from B on BO_2 to find B'; draw $B'G$ and produce it to intersect the arc APG in P'. Then P' is the P.C.C. required. Join $P'O_1$ and produce it to meet BO_2 produced in O_2'. The

$P'O_2' = B'O_2' = R_2'$, the new radius, with which describe the arc $P'B'$.

By Geom. Table XLI, 18:

$$PBV = \tfrac{1}{2}PO_2B = \tfrac{1}{2}\Delta_2, \text{ and } GB'V' = \tfrac{1}{2}P'O_2'B' = \tfrac{1}{2}\Delta_2'.$$

$$\therefore \qquad PGP' = BGB' = \tfrac{1}{2}(\Delta_2 - \Delta_2')$$

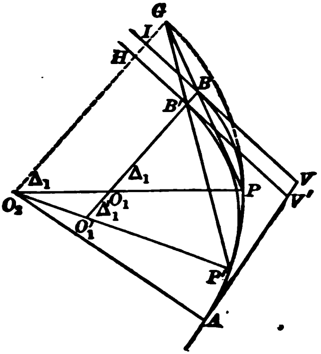

FIG. 49.

Draw O_1K perpendicular to BO_2.

Then $O_1K = B'H = BI = O_1O_2 \sin \Delta_2 = (R_2 - R_1) \sin \Delta_2$.

$$\tan \tfrac{1}{2}\Delta_2 = \frac{GI}{BI} \qquad \tan \tfrac{1}{2}\Delta_2' = \frac{GH}{B'H} = \frac{GI - p}{B'H}$$

$$\therefore \qquad \tan \tfrac{1}{2}\Delta_2' = \tan \tfrac{1}{2}\Delta_2 - \frac{p}{(R_2 - R_1) \sin \Delta_2} \qquad (121)$$

In the triangle $O_1O_2O_2'$

$$\sin \Delta_2' : \sin \Delta_2 :: O_1O_2 : O_1O_2' :: (R_2 - R_1) : (R_2' - R_1)$$

$$R_2' - R_1 = \frac{\sin \Delta_2}{\sin \Delta_2'} (R_2 - R_1)$$

and

$$R_2' = (R_2 - R_1) \frac{\sin \Delta_2}{\sin \Delta_2'} + R_1 \qquad (122)$$

If B'V' were **outside** *of VB,*

$$\tan \tfrac{1}{2}\Delta_2' = \tan \tfrac{1}{2}\Delta_2 + \frac{p}{(R_2 - R_1)\sin \Delta_2} \qquad (123)$$

$$R_2' = (R_2 - R_1)\frac{\sin \Delta_2}{\sin \Delta_2'} + R_1 \qquad (122)$$

When the **smaller radius** R_1 follows R_2: *If the given tangent B'V' is* **inside** *of BV.* Fig. 49.

$$\tan \tfrac{1}{2}\Delta_1' = \tan \tfrac{1}{2}\Delta_1 + \frac{p}{(R_2 - R_1)\sin \Delta_1} \qquad (124)$$

$$R_1' = R_2 - (R_2 - R_1)\frac{\sin \Delta_1}{\sin \Delta_1'} \qquad (125)$$

If B'V' is **outside** *of BV:*

$$\tan \tfrac{1}{2}\Delta_1' = \tan \tfrac{1}{2}\Delta_1 - \frac{p}{(R_2 - R_1)\sin \Delta_1} \qquad (126)$$

$$R_1' = R_2 - (R_2 - R_1)\frac{\sin \Delta_1}{\sin \Delta_1'} \qquad (125)$$

Example 1.—Fig. 48.

Let	$R_2 = 2292.01$	$p = 20.07$ *inside.*			
	$R_1 = 1432.69$	$\Delta_2 = 28°$			
(121)	$R_2 - R_1 =$	859.32		log	2.934155
	Δ_2		28°	log sin	9.671609
					2.605764
	p	20.07			1.302547
		.04975			8.696783
	$\tan \frac{1}{2}\Delta_2$	.24933			
∴	$\tan \frac{1}{2}\Delta_2'$	.19958	11° 17'		
(122)	Δ_2'		22° 34'	sin	9.584058
	$(R_2 - R_1)$				2.934155
					3.350097
	Δ_2		28°	sin	9.671609
	$(R_2' - R_1)$	1051.25			3.021706
	R_1	1432.69			

Ans. $R_2' = 2483.94$ ∴ $D = 2° 18' 25''$

$PO_1P = 28° - 22° 34' = 5° 26'$ ∴ PP' = 135.83 ft.

Example 2.—*Fig.* 49.

Let $R_2 = 2292.01 \qquad p = 20.07$ inside.

$R_1 = 1432.69 \qquad \Delta_1 = 46°$

Ans. $R_1' = 1474.41 \quad \therefore D = 3° 53' 12''$

$$PO_2P' = \Delta_1' - \Delta_1 = 3° 07' \therefore \text{arc } PP' = \frac{3°.1166}{2.5} = 124.67 \text{ ft.}$$

Observe that in either figure both tangents must be on the same side of the point G, in order to a solution.

171. *Given: a compound curve ending in a tangent, to change the* **last radius** *and also the position of the* **P.C.C.,** *so that the curve may end in the* **same tangent.** Fig. 50.

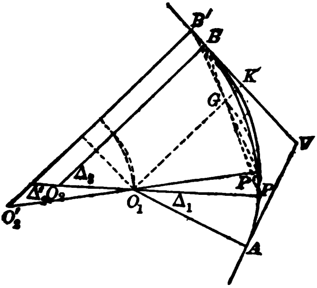

FIG. 50.

I. *When the curve ends with the* **greater** *radius* R_2.

Let APB be the compound curve in which R_1, R_2, Δ_1 and Δ_2 are known.

In the diagram draw the chord PB and produce the first arc AP to meet it in G; draw O_1G, and produce it to meet the tangent in K. Then by § 137 O_1K is parallel to O_2B, by eq. (57)

$$GK = (R_2 - R_1) \text{ vers } \Delta_2 \tag{127}$$

If we **assume P′** *as the new* P.C.C., *we have* $\Delta_2' = P'O_2'B'$, and the chord $P'G$ produced will intersect the tangent at the new point of tangent B', and $B'O_2' = R_2'$. Similar to eq. (127) we have

$$GK = (R_2' - R_1) \text{ vers } \Delta_2'$$

and equating the two expressions, we obtain

$$R_2' = R_1 + \frac{(R_2 - R_1)\text{ vers }\Delta_2}{\text{vers }\Delta_2'} = R_1 + \frac{GK}{\text{vers }\Delta_2'} \tag{128}$$

If we **assume R₂′**, *we have*

$$\text{vers }\Delta_2' = \frac{R_2 - R_1}{R_2' - R_1}\text{ vers }\Delta_2 = \frac{GK}{R_2' - R_1} \tag{129}$$

In the two right-angled triangles BKG and $B'KG$, we have

$$BK = GK \cot \tfrac{1}{2}\Delta_2$$

$$B'K = GK \cot \tfrac{1}{2}\Delta_2'$$

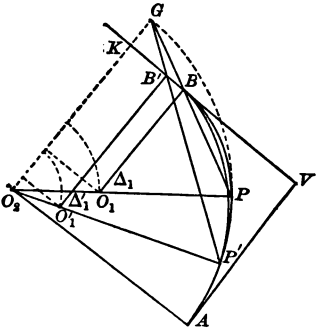

FIG. 51.

and by subtraction,

$$BB' = GK\,(\cot \tfrac{1}{2}\Delta_2' - \cot \tfrac{1}{2}\Delta_2) \tag{130}$$

in which GK is obtained from eq. (127).

When BB' as given by eq. (130) is *negative*, the point B' falls between B and V.

If we **assume** *the distance* **BB′** *on the tangent*, we have from the last equation,

$$\cot \tfrac{1}{2}\Delta_2' = \cot \tfrac{1}{2}\Delta_2 \pm \frac{BB'}{GK} \tag{131}$$

GK being obtained from eq. (127) and R_2' from eq. (128). In eq. (131) use the + sign when B' is beyond B as in *Fig. 50.*

II. *When the given curve ends with the* **smaller radius** R_1. Fig. 51.

We have by a similar reasoning

$$GK = (R_2 - R_1) \text{ vers } \Delta_1 \tag{132}$$

$$R_1' = R_2 - \frac{(R_2 - R_1) \text{ vers } \Delta_1}{\text{vers } \Delta_1'} = R_2 - \frac{GK}{\text{vers } \Delta_1'} \tag{133}$$

$$\text{vers } \Delta_1' = \frac{R_2 - R_1}{R_2 - R_1'} \text{ vers } \Delta_1 = \frac{GK}{R_2 - R_1'} \tag{134}$$

$$BB' = GK\,(\cot \tfrac{1}{2}\Delta_1 - \cot \tfrac{1}{2}\Delta_1') \tag{135}$$

$$\cot \tfrac{1}{2}\Delta_1' = \cot \tfrac{1}{2}\Delta_1 \pm \frac{BB'}{GK} \tag{136}$$

using the − sign when B' is beyond B.

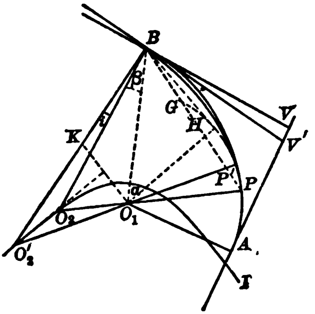

FIG. 52.

Example.—Fig. 51.

Let $R_2 = 2291.01$, $R_1 = 1432.69$, $\Delta_1 = 46°$, and let the P.C.C. be moved back 200 feet from P to P'; hence $PO_2'P' = 5°$ and $\Delta_1' = 51°$; to find the new radius R_1' and the distance BB'.

Use eqs. (132), (133) and (135).

Ans. $R_1' = 1584.16$; $D = 3° 37'$; and $BB' = 68.04$.

172. *Given: a compound curve ending in a tangent, the last radius being the* **greater, to change** *the* **last radius** *and also the position of the* **P.C.C.** *so that the curve may end at the* **same tangent point,** *but with a given difference in* **direction** *of the tangent.* Fig. 52.

Let APB be the given compound curve, $PO_1 = R_1$ and $PO_2 = R_2 > R_1$.

Let $V'B$ be the new tangent, and the angle $VBV' = i$, the given difference in direction: to find $BO_2' = R_2'$, $BO_2'P' = \Delta_2'$ and the angle PO_1P'.

We have

$$BO_2 - O_1O_2 = R_2 - (R_2 - R_1) = R_1$$

$$BO_2' - O_1O_2' = R_2' - (R_2' - R_1) = R_1$$

From which we see that whatever may be the value of the new radius, the *difference* of the distances from B and O_1 to the new center is *constant*, and equal to R_1. We therefore conclude that the centers O_2 and O_2' are on an *hyperbola* of which B and O_1 are the foci, and R_1 the major axis.

This suggests an easy **graphical method** of solving the problem.

Through B draw a line perpendicular to the new tangent $V'B$ which will give the direction of the required center O_2'. On this line lay off BK equal to R_1, and since $(R_2' - R_1) = O_1O_2' = KO_2'$, if we join KO_1, the triangle $KO_2'O_1$ is isosceles; therefore bisect KO_1 and erect a perpendicular from the middle point to intersect the line BK produced in O_2'. Draw $O_2'O_1$ and produce it to intersect the arc AP (produced if necessary) in P'. Then P' is the new P.C.C. required, and $BO_2' = P'O_2' = R_2'$, the new radius.

The analytical solution is as follows:

Adopting the usual notation of the hyperbola

Let $2a = R_1$ = the major axis;
$2c = BO_1$ = the distance between foci.

Produce the arc AP and through B draw the tangent BH, and join $HO_1 = R_1$. Then in the right-angled triangle BHO_1

$$BH^2 = BO_1^2 - R_1^2 = 4c^2 - 4a^2$$

Now by Anal. Geom., $c^2 - a^2 = b^2$.

Therefore $2b = BH$ = the minor axis.

Draw the chord PB and produce the arc AP to cut it in G.

Then by Geom. (Table XLI, 24),

$$BH^2 = PB \times GB = 2R_2 \sin \tfrac{1}{2}\Delta_2 \times 2(R_2 - R_1) \sin \tfrac{1}{2}\Delta_2$$

$$\therefore \qquad BH = 2 \sin \tfrac{1}{2}\Delta_2 \sqrt{R_2 (R_2 - R_1)} \tag{137}$$

Let α = the angle HO_1B, then

$$\tan \alpha = \frac{BH}{R_1} \text{ and } BO_1 = \frac{R_1}{\cos \alpha} \tag{138}$$

In the triangle BO_1O_2 let $O_1BO_2 = \beta$; then

$$\sin \beta = \frac{R_2 - R_1}{BO_1} \sin \Delta_2 \tag{139}$$

The polar equation of the hyperbola for the branch IO_2O_2', taking the pole at B and estimating the variable angle v from the line BO_1, is

$$r = \frac{b^2}{c \cdot \cos v - a}$$

When $v = \beta \pm i$, $r = R_2'$, and substituting the values of a, b, and c found above, we have

$$R_2' = \frac{BH^2}{2(BO_1 \cos (\beta \pm i) - R_1)} \tag{140}$$

using $(\beta + i)$ when V' falls between V and A, as in the figure, and $(\beta - i)$ when V' falls beyond V.

In the triangle BO_1O_2', the angle $BO_2'O_1 = \Delta_2'$ and

$$\sin \Delta_2' = \frac{BO_1}{R_2' - R_1} \sin (\beta \pm i) \tag{141}$$

Finally

$$PO_1P' = \Delta_2 - (\Delta_2' \pm i) \tag{142}$$

Remark.—When V' falls between V and A, as in Fig. 52, if the angle i be greater than the angle VBH, the curve ceases to be a compound, and becomes reversed. Therefore $VBH = \alpha - \beta$ is the maximum value of i possible in this case. When V' falls beyond V, the point P' will fall between P and A; and the largest possible value of i will then be that which renders $PO_1P' = \Delta_1$, and makes the point P' coincide with A.

Example.—Fig. 52. Let $R_1 = 1432.69$ $\quad \Delta_1 = 31°$
$i = 6°$ $\quad R_2 = 2292.01$ $\quad \Delta_2 = 56°$

Use eqs. (137), (138), (139), (140), (141) and (142).

Ans. log BH = 3.119825; α = 42° 36′ 23″.7;
log BO' = 3.289262; β = 21° 28′ 06″.3; R_2' = 2949.05;
Δ_2' = 36° 18′ 26″; PO_1P' = 13° 41′ 34″ = 342.3 feet.

Remark.—This problem may also be solved by first finding the new sides $V'A$, $V'B$, from which and the new central angle ($\Delta \pm i$), and the radius R_1, may be found Δ_1', Δ_2', and R_2', as in § 162. The new sides are readily found from the old ones by solving the triangle VBV'. If the original sides are not given, they must be calculated as in § 164.

173. *Given: a compound curve ending in a tangent, the last radius being the* **less,** *to change the* **last radius** *and the position of the* **P.C.C.** *so that the curve may end at the* **same tangent point,** *but with a* **given difference** *in the* **direction** *of tangent.* Fig. 53.

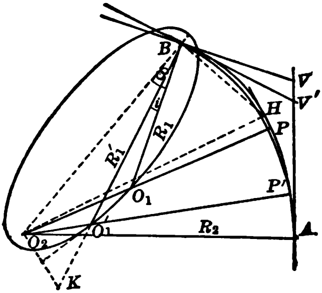

Fig 53.

Let APB be the given curve, and $PO_2 = R_2$, and $PO_1 = R_1 < R_2$. Let $V'B$ be the new tangent, and $VBV' = i$ the given angle; to find $BO_1' = R_1'$, $BO_1'P'$, $= \Delta_1'$, and the angle PO_2P'.

We have

$$BO_1 + O_1O_2 = R_1 + (R_2 - R_1) = R_2$$

$$BO_1' + O_1'O_2 = R_1' + (R_2 - R_1') = R_2$$

from which we infer that the locus of the center O_1' is an *ellipse*, of which B and O_2 are the foci, and R_2 the major axis, since the *sum* of the distances BO_1' and O_2O_1' is always *al to R_2.*

This suggests an easy **graphical solution** of the problem, as follows:

Perpendicular to $V'B$ draw the indefinite line BK, which will contain the required center O_1', and lay off $BK = R_2$. Join KO_2, bisect it, and from the middle point erect a perpendicular to intersect BK in O_1'. Join O_2O_1', and produce the line to intersect the arc AP (produced if necessary) in P', which is the new P.C.C. required. $P'O_1' = BO_1' = R_1'$ the required radius, and $P'O_1'B = \Delta_1'$.

The analytical solution is as follows: Adopting the usual notation of the ellipse,

let $2a = R_2$ = the major axis,
$2c = BO_2$ = the distance between foci.

At B erect BH perpendicular to BO_2 to intersect the arc AP (produced if necessary) in H, and join $HO_2 = R_2$. Then

$$BH^2 = R_2^2 - BO_2^2 = 4a^2 - 4c^2$$

But by Anal. Geom., $a^2 - c^2 = b^2$.

Hence $2b = BH$ = the minor axis.

In the triangle BO_1O_2 we know $BO_1 = R_1$, and $O_1O_2 = R_2 - R_1$, and the included angle $BO_1O_2 = 180° - \Delta_1$; hence by Trig. (Table XLII, 25)

$$\tan \tfrac{1}{2}(O_1O_2B - O_1BO_2) = \frac{2R_1 - R_2}{R_2} \tan \tfrac{1}{2}\Delta_1 \qquad (143)$$

The angles at B and O_2 are then found by Table XLII, 26). Let β = the angle O_1BO_2; then

$$BO_2 = (R_2 - R_1)\frac{\sin \Delta_1}{\sin \beta} \qquad (144)$$

The value of BH^2 above may be written

$$BH^2 = (R_2 + BO_2)(R_2 - BO_2) \qquad (145)$$

The polar equation of the ellipse, taking the pole at B, and estimating the variable angle v from the axis BO_2, is

$$r = \frac{b^2}{a - c \cdot \cos v}$$

When $v = \beta \mp i$, then $r = R_1'$, and substituting the values of a, b, and c, given above, we have

$$R_1' = \frac{BH^2}{2(R_2 - BO_2 \cos(\beta \mp i))} \tag{146}$$

using $(\beta - i)$ when V' falls between V and A, as in Fig. 53, and $(\beta + i)$ when V' falls beyond V.

In the triangle $BO_1'O_2$, the angle $O_1'BO_2 = (\beta \mp i)$, and the exterior angle $BO_1'P' = \Delta_1'$; hence

$$\sin \Delta_1' = \frac{BO_2}{R_2 - R_1'} \sin(\beta \mp i) \tag{147}$$

Finally $$PO_2P' = (\Delta_1 \mp i) - \Delta_1' \tag{148}$$

When V' is on AV, then PO_2P' is negative, showing that it must be laid off from P toward A; but when V' is beyond V, then PO_2P' is positive, and P' will be on AP produced. The only limits imposed on the angle i are that the resulting value of PP' shall not exceed PA, and that R_1' shall not be less than a practical minimum.

Example.—Fig. 53.

Let $D_2 = 3° 20'$ $R_2 = 1719.12$ $\Delta_2 = 23° 20'$
$D_1 = 6°$ $R_1 = 955.37$ $\Delta_1 = 48°$ $i = 7° 45'$

The resulting values are as follows:

β		21° 09′ 32″.6	
BO_2	1572.42		log 3.196567
BH^2			" 5.683829
R_1'	1273.65		" 3.105052
Δ_1'		54° 56′	
PO_2P'		14° 41′	
PP'	440.5		

(See also remark at end of § 172.)

174. *Given a* **simple curve** *joining two tangents, to replace it by a* **three-centered compound** *curve between the same* **ngent points**, Fig. 54.

Let $R = AO$ = radius of simple curve.

$R_1 = PO_1 = P'O_1 < R \quad \Delta_1 = PO_1P'$

$R_2 = AO_2 = BO_3 > R \quad \Delta_2 = AO_2P = BO_3P'$

$\Delta = AOB$

Since AO_2 is made equal to BO_3 and $VA = VB$, AO_2P *must* equal BO_3P', and the compound curve will be symmetrical about the bisecting line VO; and the center O_1 will be on the line VO.

We have at once from the figure,

$$2\Delta_2 + \Delta_1 = \Delta \tag{149}$$

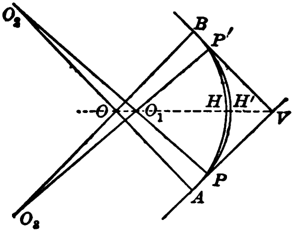

FIG. 54.

In the triangle OO_1O_2 we have

$$O_1O_2 : OO_2 :: \sin AOV : \sin PO_1V$$

whence

$$R_2 - R_1 = \frac{(R_2 - R) \sin \frac{1}{2}\Delta}{\sin \frac{1}{2}\Delta_1} \tag{150}$$

which expresses the general relation between the quantities, R and Δ being given.

We may now assume values for R_1 *and* R_2 subject to the above conditions, viz., $R_1 < R$ and $R_2 > R$; whence

$$\sin \tfrac{1}{2}\Delta_1 = \frac{(R_2 - R) \sin \frac{1}{2}\Delta}{R_2 - R_1} \tag{151}$$

In selecting values for R_1 and R_2, the degree of curve D_1 should be but little greater than D of the simple curve, say from 30 *to 60 minutes*, while D_2 may be taken at $\frac{1}{2}D$ to $\frac{1}{4}D$.

Example.—Given; $R = 1719.12 \quad D = 3° 20' \quad \Delta$

Let $R_1 = 1432.69 \quad D_1 = 4°$

$R_2 = 5729.65 \quad D_2 = 1°$

∴	$R_2 - R$	4010.53	log 3.603202
	$R_2 - R_1$	4296.96	" 3.633161
			" 9.970041
	$\frac{1}{2}\Delta$	20°	log sin 9.534052
∴	$\frac{1}{2}\Delta_1$	18° 36′ 57″	" 9.504093
	Δ_1	37° 13′ 54″	
∴	Δ_2	1° 23′ 03″	
	$AP = P'B$	138.4 feet	

Again we may assume Δ_2 *and* R_1, whence

$$\Delta_1 = \Delta - 2\Delta_2$$

and

$$R_2 = \frac{R \sin \frac{1}{2}\Delta - R_1 \sin \frac{1}{2}\Delta_1}{\sin \frac{1}{2}\Delta - \sin \frac{1}{2}\Delta_1} \qquad (152)$$

Example.—Given: $R = 1719.12 \quad \Delta = 40°$

Let $R_1 = 1432.69 \qquad \Delta_2 = 1° \qquad \therefore\ \Delta_1 = 38°$

Ans. $R_2 = 7387.24 \ \therefore\ D_2 = 0° 46\frac{1}{2}' \quad AP = 129.$

Finally we may assume Δ_2 *and* R_2, and deduce Δ_1 and R_1 from eqs. (149) (150); but this is the least desirable because the value of R_1 so found will not usually give a convenient value to the degree of curve D_1.

175. *To determine the* **distance HH′** *between the middle points of a simple curve and a three-centered compound curve joining the* **same tangent points** *AB*. Fig. 54.

In the triangle OO_1O_2, we have

$$OO_1 = (R_2 - R_1)\frac{\sin \Delta_2}{\sin \frac{1}{2}\Delta}$$

$$HH' = OO_1 + O_1H' - OH$$

$$\therefore \qquad HH' = (R_2 - R_1)\frac{\sin \Delta_2}{\sin \frac{1}{2}\Delta} - (R - R_1) \qquad (153)$$

In the first example given above $HH' = 14.55$, and in the second $HH' = 17.05$ feet.

In many instances the distance HH' is so great as to render *problem practically* useless, unless the distance HH′ is discounted beforehand by putting the simple curve *AHB* a sufficient distance inside of the proper location through the point *H'*. But the problem given below is usually preferable.

176. *Given, a* **simple curve** *joining two tangents to replace it by a* **three-centered compound** *curve which shall pass through the* **same middle point H.**

I. *The curve* **flattened at the tangents.** **Fig. 55.**

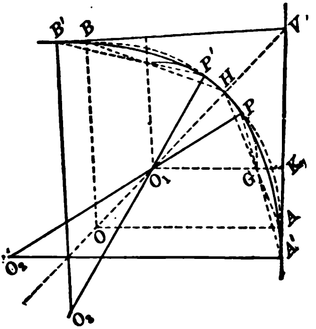

FIG. 55.

Let $R = AO$, the radius, and $\Delta =$ the central angle of the simple curve *AHB*, and let *H* be the middle point.

Let $R_1 = PO_1 = HO_1$ $\quad\quad \Delta_1 = PO_1P'$

$R_2 = PO_2 = A'O_2 = B'O_3$ $\quad\quad \Delta_2 = PO_2A' = P'O_3B'$

and, *A'* and *B'* be the new tangent points required.

We have at once, as in the last problem,

$$2\Delta_2 + \Delta_1 = \Delta \tag{154}$$

Since the curve is to be symmetrical about *VO*, $HP = HP'$. $PA = P'B$, and $AA' = BB'$.

In the diagram produce the arc *HP* to *G*, and draw O_1G parallel to *OA*, and produce it to *K*. Then a tangent line at *G* will be parallel to *VA*; and by § 137 the point G will be on the long chord *HA*, and on the long chord PA'. GK is *the perpendicular* distance between parallel tangents, an the problem is similar to that given in § 171; **whence** eq. (57) we have, in this case,

$$GK = (R_2 - R_1) \text{ vers } \Delta_2 = (R - R_1) \text{ vers } \tfrac{1}{2}\Delta \qquad (15$$

for the general equation in which R and Δ are given.

Analagous to eq. (130) we have

$$AA' = KA' - KA = GK \cot GA'K - GK \cot GAK.$$

$$\therefore \qquad AA' = GK\,(\cot \tfrac{1}{2}\Delta_2 - \cot \tfrac{1}{2}\Delta) \qquad (15$$

in which GK is obtained from (155).

We may now assume values for R_1 and R_2, making $R_1 <$ and $R_2 > R$, and deduce the values of Δ_2, Δ_1, and AA'.

Solving eq. (155)

$$\text{vers } \Delta_2 = \frac{(R - R_1) \text{ vers } \frac{1}{2}\Delta}{R_2 - R_1} = \frac{GK}{R_2 - R_1} \qquad (15$$

Eq. (154) gives Δ_1, and eq. (156) gives AA'.

Example.—Fig. 55.

Given:	$R = 764.489$	$D = 7° 30'$	$\Delta = 40°$
Let	$R_1 = 716.779$	$D_1 = 8°$	
	$R_2 = 3437.870$	$D_2 = 1° 40'$	

Use eqs. (155) and (156) and (157).

Ans. $\Delta_2 =$ (say) $2° 38'$, $AA' = 108.87$.

Again, we may assume Δ_2 and $R_1 < R$; whence

$$\Delta_1 = \Delta - 2\Delta_2$$

and

$$\text{eq. (155)} \quad GK = (R - R_1) \text{ vers } \tfrac{1}{2}\Delta$$

and

$$R_2 = R_1 + \frac{GK}{\text{vers } \Delta_2} \qquad (15$$

Eq. (156) gives AA'.

Again, we may assume Δ_2 and the distance AA'; whenc from eq. (156)

$$GK = \frac{AA'}{\cot \frac{1}{2}\Delta_2 - \cot \frac{1}{2}\Delta} \qquad (15$$

$$\text{eq. (155)} \quad R_1 = R - \frac{GK}{\text{vers } \frac{1}{2}\Delta}$$

7. (158) gives R_2.

Again, we may assume $R_1 < R$ and AA'; then, eq. (155)

$$GK = (R - R_1) \text{ vers } \tfrac{1}{2}\Delta$$

and eq. (156)

$$\cot \tfrac{1}{2}\Delta_2 = \cot \tfrac{1}{2}\Delta + \frac{AA'}{GK} \qquad (160)$$

and eq. (158) gives R_2.

Example.—Fig. 55.

Given: $R = 764.489$ $D = 7° 30'$ $\Delta = 40°$
Let $R_1 = 716.779$ $D_1 = 8°$
$AA' = 110$
Use eqs. (160) and (158).
Ans. $R_2 = 3476.3$; $D_2 = 1° 39'$; $AP' = $ **157.0**, $\Delta_1 = 34° 46'$.

II. *The curve* **sharpened at the tangents.** Fig. 56.
This case will occur only when, with a given external distance VH, a simple curve would absorb too much of the tangents.

Let AHB be the simple curve, and
$A'PHP'B'$, the required compound curve

$$R_2 = PO_2 = HO_2; \qquad \Delta_2 = PO_2P'$$

$$R_1 = PO_1 = A'O_1 = B'O_3; \qquad \Delta_1 = A'O_1P = P'O_3B'.$$

We have from the figure,

$$2\Delta_1 + \Delta_2 = \Delta \qquad (161)$$

In the diagram draw O_2G parallel to OA, cutting the tangent at K, and produce the arc HP to G. Draw the chords GH and GP, passing through A and A' respectively. We have then a discussion similar to the preceding case, and to the problem § 171, Fig. 51, whence we derive the general formulas:

$$GK = (R_2 - R_1) \text{ vers } \Delta_1 = (R_2 - R) \text{ vers } \tfrac{1}{2}\Delta \qquad (162)$$

and

$$AA' = GK\,(\cot \tfrac{1}{2}\Delta_1 - \cot \tfrac{1}{2}\Delta) \qquad (163)$$

1. Assuming $R_1 < R$ and $R_2 > R$

$$\text{vers } \Delta_1 = \frac{GK}{R_2 - R_1} = \frac{R_2 - R}{R_2 - R_1} \text{ vers } \tfrac{1}{2}\Delta \qquad (164)$$

2. Assuming $\Delta_1 < \frac{1}{2}\Delta$ and $R_1 < R$

$$R_2 = \frac{R \text{ vers } \frac{1}{2}\Delta - R_1 \text{ vers } \Delta_1}{\text{vers } \frac{1}{2}\Delta - \text{vers } \Delta_1} \tag{165}$$

3. Assuming $\Delta_1 < \frac{1}{2}\Delta$ and AA'

$$GK = \frac{AA'}{\cot \frac{1}{2}\Delta_1 - \cot \frac{1}{2}\Delta} \tag{166}$$

$$R_2 = R_1 + \frac{GK}{\text{vers } \Delta_1} \tag{167}$$

$$R_1 = R_2 - \frac{GK}{\text{vers } \Delta_1} \tag{168}$$

4. Assuming $R_2 > R$ and AA'

$$GK = (R_2 - R) \text{ vers } \tfrac{1}{2}\Delta$$

$$\cot \tfrac{1}{2}\Delta_1 = \cot \tfrac{1}{2}\Delta + \frac{AA'}{GK} \tag{169}$$

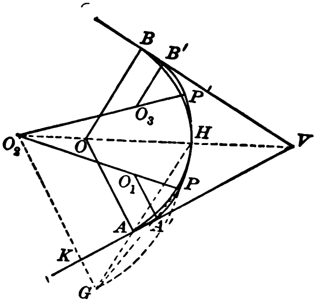

FIG. 56.

The third assumption will usually secure most readily the desired curve. AA' should be assumed as small as the nature of the case will allow, and Δ_1 should not be much smaller than $\frac{1}{2}\Delta$.

It is evidently not *necessary* that the new curve should be symmetrical; for having laid out the curve *A'PH*, the simple curve *HB* may then be used, or, if desirable, some compound curve *HP'B'* determined by an assumed value *BB' not equal to AA'.*

These formulas (154) to (169) are readily adapted to the case of substituting a compound for a simple curve when it is necessary to keep one tangent point fixed, but to move the other a certain distance in either direction on the tangent. For if in Figs. 55, 56, we draw a tangent at H, and make H the fixed point of tangent, it is evident that the central angle of the curve will then be AOH. The only change necessary, therefore, to adapt the formulas to this case is to write Δ in place of $\frac{1}{2}\Delta$, and to observe, instead of eqs. (154), (161), that

$$\Delta_1 + \Delta_2 = \Delta.$$

Example.—Fig. 55.

Let $R = 1910.08$ $\Delta = 84°$

Assume $AA' = 260.$ $\Delta_1 = 38°$ $\therefore\ \Delta_2 = 8°$

Use eqs. (166), (167) and (168).

Ans. $R_2 = 5294.15$; $R_1 = 1193.88$; $D = 4° 48'$; $A'P = 791.67$; and $PH = 369.23$.

177. *Given,* **two curves** *joined by a common tangent* **to replace the tangent by a curve** *compounded with the given curves.* Fig. 57.

Let $R_1 = BO_1$ the radius of one curve;
$R_3 = AO_3$ the radius of the other curve, $> R_1$;
$l = BA$ the common tangent;
$R_2 = PO_2 = P'O_2$ the radius of connecting curve;
$\Delta_2 = PO_2P'$ the central angle of connecting curve;
$\alpha = AO_3P'$ and $\beta = BO_1P$;
$i = AO_3O_1$.

In the diagram join O_1O_3 and draw O_1G parallel to BA. Then in the right-angled triangle O_1GO_3 we have,

$$\cot i = \frac{GO_3}{GO_1} = \frac{R_3 - R_1}{l} \tag{170}$$

$$O_1O_3 = \frac{R_3 - R_1}{\cos i} = \frac{l}{\sin i} \tag{171}$$

which gives the distance between the centers of the given curves.

We shall now assume the following geometrical truths, which may be *easily* demonstrated.

If two circles intersect in one point, they intersect in tw points; and the line joining the two points is the common chord.

The common chord is perpendicular to the line joining the centers, and when produced it bisects the common tangents.

If a third circle is drawn touching the two circles, a tangent to the third circle, parallel to the common tangent, will have its tangent point on the common chord produced.

Conversely, therefore, if the tangent BA be bisected at K, and a line, KI, drawn perpendicular to O_1O_3, KI will coincide with the common chord produced, and the angle IKA = $AO_3O_1 = i$. If on KI we assume a point I through which it is desirable that the connecting curve should pass, then I is the tangent point of a tangent parallel to BA; consequently a line through I perpendicular to BA contains the required center O_2.

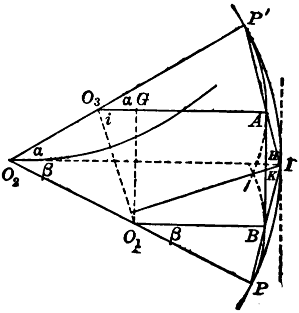

FIG. 57.

I. Let $p = HI$ = the perpendicular distance between the tangents.

If in the diagram we join IA and IB, and produce the chords to intersect the given curves in P and P', then P and P' are the points of compound curvature; and the lines PO_1 and $P'O_3$ produced will intersect IO_2 in the same point O_2; and the angles $P'O_2I = \alpha$, and $PO_2I = \beta$.

In the triangle AIB the line KI bisects the base AB, and *e have by* Geom. Table XLI, 25.

$$AI^2 + BI^2 = 2AK^2 + 2KI^2$$

By eq. (56)
$$AI = 2(R_2 - R_3) \sin \tfrac{1}{2}\alpha$$
$$BI = 2(R_2 - R_1) \sin \tfrac{1}{2}\beta$$
$$AK = \tfrac{1}{2}l \text{ and } KI = \frac{p}{\sin i}$$

$$\therefore \quad 4(R_2 - R_3)^2 \sin^2 \tfrac{1}{2}\alpha + 4(R_2 - R_1)^2 \sin^2 \tfrac{1}{2}\beta = \tfrac{1}{2}l^2 + \frac{2p^2}{\sin^2 i}$$

Dividing by 2 and putting vers $\alpha = 2 \sin^2 \frac{1}{2}\alpha$ and vers $\beta = 2 \sin^2 \frac{1}{2}\beta$ (Table XLII, 46),

$$(R_2 - R_3)^2 \operatorname{vers} \alpha + (R_2 - R_1)^2 \operatorname{vers} \beta = \tfrac{1}{4}l^2 + \frac{p^2}{\sin^2 i}$$

But by eq. (57)

$$(R_2 - R_3) \operatorname{vers} \alpha = (R_2 - R_1) \operatorname{vers} \beta = p \tag{172}$$

$$p(2R_2 - (R_3 + R_1)) = \tfrac{1}{4}l^2 + \frac{p^2}{\sin^2 i}$$

$$2R_2 = (R_3 + R_1) + \frac{l^2}{4p} + \frac{p}{\sin^2 i} \tag{173}$$

From (172)

$$\operatorname{vers} \alpha = \frac{p}{R_2 - R_3}; \quad \operatorname{vers} \beta = \frac{p}{R_2 - R_1} \tag{174}$$

and from the figure

$$\Delta_2 = \alpha + \beta \tag{175}$$

These formulas solve the problem when p is assumed. If desirable we may find α and β independently of R_2, for in the triangle AIB, $IAB = \frac{1}{2}\alpha$ and $IBA = \frac{1}{2}\beta$; and since $HK = p \cot i$,

$$\cot \tfrac{1}{2}\alpha = \frac{AH}{HI} = \frac{\tfrac{1}{2}l - HK}{p} = \frac{l}{2p} - \cot i \tag{176}$$

$$\cot \tfrac{1}{2}\beta = \frac{BH}{HI} = \frac{\tfrac{1}{2}l + HK}{p} = \frac{l}{2p} + \cot i \tag{177}$$

II. *In case α or β is assumed,* we have from the last equation

$$p = \frac{l}{2(\cot \tfrac{1}{2}\alpha + \cot i)} = \frac{l}{2(\cot \tfrac{1}{2}\beta - \cot i)} \quad (178$$

III. *In case the radius R_2 is assumed,* then in the triangle $O_1O_2O_3$ we know all three sides; for $O_1O_2 = (R_2 - R_1)$, $O_2O_3 = (R_2 - R_3)$, and $O_1O_3 = \dfrac{R_3 - R_1}{\cos i}$.

By Trig. (Table XLII, 31)

$$\text{vers } \Delta_2 = \frac{2(s - O_1O_2)(s - O_2O_3)}{O_1O_2 \times O_2O_3}$$

in which $s = \frac{1}{2}$ sum of the three sides.

Substituting values, and reducing, observing that,

$$\left(\frac{1}{\cos i} - 1\right)\left(\frac{1}{\cos i} + 1\right) = \sec^2 i - 1 = \tan^2 i$$

and that $(R_3 - R_1) \tan i = l$, we have

$$\text{vers } \Delta_2 = \frac{l^2}{2(R_2 - R_1)(R_2 - R_3)} \tag{179}$$

In the same triangle

$$\sin O_3O_1O_2 = \sin \Delta_2 \frac{O_3O_2}{O_1O_3} = \sin (i - \beta) \tag{179a}$$

for from the figure $O_3O_1O_2 = i - \beta$, and taking the value of O_1O_3 from eq. (171)

$$\sin (i - \beta) = \frac{(R_2 - R_3) \sin \Delta_2 \sin i}{l} \tag{180}$$

We then find α from eq. (175) and p from (172).

The angles α and β may be found otherwise, for by Trig. (Table XLII, 27) we have in the triangle $O_1O_2O_3$

$$\sin \tfrac{1}{2}(O_1O_3O_2 - O_3O_1O_2) = \frac{O_1O_2 - O_2O_3}{O_1O_3} \cos \tfrac{1}{2}\Delta_2$$

or

$$\sin \left(90° - \left(i + \frac{\alpha - \beta}{2}\right)\right) = \frac{(R_3 - R_1) \cos i \cos \frac{1}{2}\Delta_2}{R_3 - R_1}$$

$$\therefore \qquad \cos \left(i + \frac{\alpha - \beta}{2}\right) = \cos i \cdot \cos \tfrac{1}{2}\Delta_2 \tag{181}$$

which is a convenient formula when i and Δ_2 are not too small. Having obtained $\dfrac{\alpha - \beta}{2}$, we have

$$\alpha = \tfrac{1}{2}\Delta_2 + \frac{\alpha - \beta}{2} \qquad \beta = \tfrac{1}{2}\Delta_2 - \frac{\alpha - \beta}{2} \tag{182}$$

a constant value of l the *less* the difference of $R_3 - R_1$ *ater* will be the value of the angle i. When $R_3 = R_1$, 0 and $i = 90°$ and the tangent point I will be on a dicular to BA drawn through the middle point K; $= \beta$. On the contrary, as $(R_3 - R_1)$ increases, i s less, and the foot, H, of the perpendicular HI toward B, the tangent point of the curve of smaller R_1. The distance $HK = p \cot i$. The connecting is farthest from the tangent BA at I. To find the e from BA to the curve at any other point, subtract the tangent offset for the length of curve from I to linate in question. § 115, eq. (39) may be used on rves with tolerable accuracy, even when the distance several hundred feet.

It is evident that in this problem R_2 must be greater ither R_1 or R_3. As the center O_2 is taken nearer the O_3, R_2 grows less, and is a minimum when O_2 falls on e O_1O_3. In this case we have $\Delta_2 = 180°$, and

$$R_2 = \tfrac{1}{2}(R_3 + R_1 + O_1O_3); \text{ a minimum.} \qquad (183)$$

limit must be regarded in assuming the value of R_2.

$${}_2 - O_2O_3 = (R_2 - R_1) - (R_2 - R_3) = (R_3 - R_1)$$

ant value, independent of R_2, we infer that the center lways on a hyperbola of which O_1 and O_3 are the foci; R_1) equals the diameter on the axis joining the foci; equals the diameter at right angles to it, for in the e O_1GO_3,

$$l^2 = \overline{O_1O_3}^2 - (R_3 - R_1)^2 \qquad (184)$$

nple.—Fig. 57.

$R_1 = 1432.69$ $R_3 = 1910.08$ and $l = 400$.

e $p = 11.4$ to find R_2, α and β.

eqs. (170), (173) and (174).

$i = 39°\ 57'\ 34''$; $R_2 = 3439.59$, called 3437.87;

00′; $\beta = 6°\ 07'$ nearly. $\Delta_2 = 13°\ 07'$.

nple.—Fig. 57.

n: $R_1 = 1432.69$, $R_3 = 1910.08$, and $l = 400$.

ne $R_2 = 3437.87$, to find Δ_2, β, α and p.

Use eqs. (179), (170), (180), (175) and (172).

Ans. $\Delta_2 = 13° 07' 22''$; $i = 39° 57' 34''$; $\beta = 6° 06' 55''$; $\alpha = 7° 00' 27''$; and $p = 11.41$.

178. *Given: a three-centered compound curve* **to replace the middle arc** *by an arc of different radius.*

I. *When the radius of the middle arc is the* **greatest.** Fig. 57.

First find the length and direction of the common tangent *AB*. Let Δ_2 = central angle of the middle arc, R_2 = its

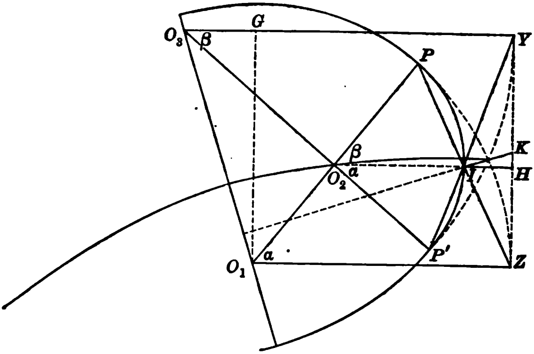

FIG. 58.

radius, and R_1 and R_3 the radii of the other arcs. From eq (179)

$$l = \sqrt{2(R_2 - R_1)(R_2 - R_3)\ \text{vers}\ \Delta_2} \qquad (185)$$

Then find i by eq. (170), α and β by eqs. (179*a*), (175), and p by eq. (172).

For the new arc we may now assume a new value for p, or for R_2, or for α. Indicating the new values by a prime, **if we assume p'** we proceed as in the last problem, using eqs. (173), etc. If we assume R_2', we use eq. (179), etc. If we assume α', we use eq. (178).

II. *When the radius of the middle arc is the* **least** *of the three.* Fig. 58.

In this case the middle arc is within the other two pro-
duced; and for the same values of R_1R_3 and O_1O_3, the *locus*

the center O_2 is the opposite branch of the hyperbola nd in § 177. When the center O_2 falls on the line O_1O_3, $= 180^\circ$, and

$$R_2 = \tfrac{1}{2}(R_3 + R_1 - O_1O_3), \text{ a maximum.} \tag{186}$$

alogous to eq. (185), we have

$$l = \sqrt{2(R_1 - R_2)(R_3 - R_2) \operatorname{vers} \Delta_2} \tag{187}$$

ich gives the length of the common tangent $YZ = GO_1$. Ve then have the values of i and of O_1O_3 by eqs. (170), 1), and of α and β by eqs. (181), (182), and analogous q. (172),

$$p = (R_1 - R_2) \operatorname{vers} \alpha = (R_3 - R_2) \operatorname{vers} \beta \tag{188}$$

vhich p is the perpendicular distance HI between parallel gents.

or the new arc we may now assume a new value for p, R_2, or α. Indicating the new values by a prime, if **assume p′**, we have, analogous to eq. (173)

$$2R_2' = R_3 + R_1 - \left(\frac{l^2}{4p'} + \frac{p'}{\sin^2 i}\right) \tag{189}$$

from eq. (188)

$$\operatorname{vers} \alpha' = \frac{p'}{R_1 - R_2}; \quad \operatorname{vers} \beta' = \frac{p'}{R_3 - R_2} \tag{190}$$

f we assume R₂′, we have, analogous to eq. (179),

$$\operatorname{vers} \Delta_2' = \frac{l^2}{2(R_1 - R_2')(R_3 - R_2')} \tag{191}$$

we find α and β by eqs. (181), (182), and p' by eq. (188).

II. *When the radius of the middle arc has an* **intermediate value,** *compared with the other radii.* Fig. 59.

n this case, whatever be the value of R_2, we have

$${}_3O_2 + O_2O_1 = (R_3 - R_2) + (R_2 - R_1) = (R_3 - R_1)$$

nstant value independent of R_2; hence we infer that the s of O_2 is an ellipse, of which O_1 and O_3 are the foci, and $- R_1)$ equal to the transverse axis.

et $l = QQ'$ = *the conjugate axis,* and let $i = QO_3O_1 =$ O_3. *Then* $QO_3 = QO_1 = \tfrac{1}{2}(R_3 - R_1)$.

Produce O_3Q to G, making $QG = O_3Q$, and join GO_1. Then by similar triangles GO_1 is perpendicular to O_1O_3, and $GO_1 = l$; and in the right-angled triangle GO_3O_1

$$\sin i = \frac{GO_1}{GO_3} = \frac{l}{R_3 - R_1} \tag{192}$$

$$O_1O_3 = (R_3 - R_1) \cos i = l \cot i \tag{193}$$

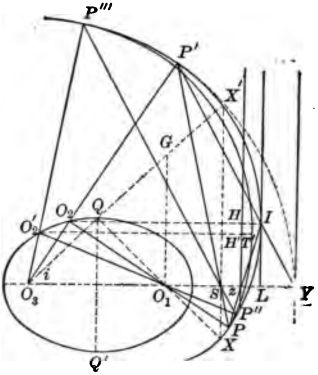

FIG. 59.

Analogous to eqs. (185) and (187), we have

$$l = \sqrt{2(R_3 - R_2)(R_2 - R_1) \operatorname{vers} \Delta_2} \tag{194}$$

which may also be derived from the triangles $O_1O_2O_3$ and O_1O_3Q.

Let $\alpha = O_2O_3O_1$, and $\beta = O_2O_1O_3$

Then

$$\sin \alpha = \frac{O_1O_2}{O_1O_3} \sin \Delta_2 = \frac{R_2 - R_1}{l} \tan i \cdot \sin \Delta_2 \tag{195}$$

From the figure $\beta = \Delta_2 - \alpha$ (196)

In the diagram produce the line O_3O_1 and it will intersect all the arcs. At the points Z and Y, where it cuts the inner and outer arcs, draw tangent lines perpendicular to O_3O_1. Draw the radius O_2I parallel to O_3O_1, and the tangent line IL at I.

Let $q = ZY$ and $p = ZL = HI$

Then by the theory of parallel tangents, § 137, the point I is on the chord PZ produced, and it is also on the chord $P'Y$; and we have

$$p = ZL = (R_2 - R_1) \text{ vers } \beta \qquad (197)$$

$$q - p = LY = (R_3 - R_2) \text{ vers } \alpha \qquad (198)$$

and q equals the *sum* of these. But $q = ZY$ is the shortest distance between the inner and outer arcs, and has a constant value independent of R_2. If we assume $R_2 = \frac{1}{2}(R_3 + R_1)$ the center O_2 will be at Q, and $\alpha = \beta = i$, and $p = \frac{1}{2}q$. Making these substitutions above,

$$q = (R_3 - R_1) \text{ vers } i \qquad (199)$$

Also, from the figure,

$$ZY = O_3Y - O_1Z - O_1O_3,$$

or

$$q = R_3 - R_1 - O_1O_3. \qquad (200)$$

In the triangle ZIY we have by Geom. Table XLI, 26,

$$ZI^2 = IY^2 + ZY^2 - 2ZY(ZY - ZL)$$

or

$$ZY^2 - 2ZY \cdot ZL = IY^2 - ZI^2$$

Now,

$$ZI^2 = 4(R_2 - R_1)^2 \sin^2 \tfrac{1}{2}\beta = 2(R_2 - R_1)^2 \text{ vers } \beta$$

$$IY^2 = 4(R_3 - R_2)^2 \sin^2 \tfrac{1}{2}\alpha = 2(R_3 - R_2) \text{ vers } \alpha$$

Hence

$$ZI^2 = 2(R_2 - R_1)p \quad \text{and} \quad IY^2 = 2(R_3 - R_2)(q - p)$$

Substituting these values, and solving for p, we have

$$p = \frac{q(R_3 - R_2 - \frac{1}{2}q)}{R_3 - R_1 - q} = \frac{q(R_3 - R_2 - \frac{1}{2}q)}{O_1O_3} \qquad (201)$$

Also

$$R_2 = (R_3 - \tfrac{1}{2}q) - p \cdot \frac{O_1O_3}{q} \qquad (202)$$

For any other value of R_2, we have

$$R_2' = (R_3 - \tfrac{1}{2}q) - p' \frac{O_1O_2}{q}$$

Hence

$$R_2' - R_2 = \frac{O_1O_3}{q}(p - p') \qquad (203)$$

which gives the change in R_2 for a given change in the value of p.

Observe that as p diminishes R_2 increases and *vice versa.*

Having determined the value of R_2', we find p' by substituting R_2' for R_2 in eq. (201); and from eqs. (197), (198) we have

$$\text{vers}\,\beta' = \frac{p'}{R_2' - R_1} \tag{204}$$

$$\text{vers}\,\alpha' = \frac{q - p'}{R_3 - R_2'} \tag{205}$$

and the change in the points of compound curvature is found by $(\beta - \beta')$ and $(\alpha' - \alpha)$.

Remark.—When $R_2 = \frac{1}{2}(R_3 + R_1)$, $\Delta_2 = 2i$, a minimum, and the long chord PP' is perpendicular to O_1O_3. When R_2 is greater than this, α is greater than β, and *vice versa.* Whatever be the value of R_2, the long chord PP' always cuts the line O_1O_3 produced in the same point S, at a distance from Z of

$$ZS = R_1\,\text{vers}\,i;$$

or from O_1 of

$$O_1S = R_1 \cos i.$$

This item will be found useful in solving the problem graphically.

Example.—

Let $R_1 = 781.84$ $D_1 = 7°\,20'$
$R_2 = 1375.40$ $D_2 = 4°\,10'$ $\Delta_2 = 48°$
$R_3 = 1910.08$ $D_3 = 3°\,00'$
$p - p' = 11.30$

Use eqs. (194), (192), (193), (195), (196), (203), (200), (201), (197) and (198).

Ans. $\log l = 2.661123$; $i = 23°\;57'\;55''$; $0_10_3 = 1030.98$, log 3.013249; $\alpha = 25°\;19'\,52''$; $\beta = 22°\,40'\,08''$; $q = 97.26$; $R_2' = 1495.18$, (say) 1494.95 for 3° 50′ curve; $p' = 34.57$; $\beta' = 17°\;55'$; $\alpha' = 31°\;54'$; $\alpha' - \alpha = 6°\;34' \therefore P'P''' = 218.89$; $\beta - \beta' = 4°\;45' \therefore PP'' = 64.77$.

The practical difficulty in changing the middle arc of three centered curves lies in the difference of measurement that ensues. Thus, in the last problem, although the total central angle is the same, the new curve is 6.56 feet shorter than the original, making a fractional station at P'''. If the change is made during the location, it is well to re-run the last arc from P''' to the tangent following, so as to eliminate the fractional station from the curve.

Instead of the solution given above we may obtain Δ_2' by

$$\text{vers } \Delta_2' = \frac{l^2}{2(R_3 - R_2')(R_2' - R_1)}$$

derived from eq. (194); and then find α' by eq. (195).

Graphical Solution.—On any well-drawn plan of the curves we may try various curve templets touching the first and third curves until we find a new middle curve to suit the required conditions.

We then take the value of its radius R_2' from Table I, subtract from R_3 and R_1 and with the differences, from the centers O_3 and O_1, draw short arcs to intersect, thus locating O_2'. We then join this point with O_1 and O_3 and produce the lines to intercept the given curves in P'' and P'''. Finally draw the long chord $P''P'''$, which must pass through the point S. The angles may then be scaled, but are better computed as before.

CHAPTER VII

REVERSED CURVES

179. A reversed curve is a combination of two simple curves of opposite curvature. There is a *common tangent* at their point of junction. The outer rails of the two arcs are on opposite sides of the track at the *point of reverse curve* (P.R.C.) and this calls for the elevation of both sides at the same time. As there is no opportunity of elevating the outer rail at the P.R.C., reversed curves should not be used where speed is desirable, as on main lines. They may be used to advantage in cross-overs and yard work, and are often imperative in the location of spur tracks to manufacturing or industrial plants.

Reversed curves may be divided into two general classes, according to whether the extreme tangents are parallel or diverging.

180. *Given: the perpendicular distance* **p,** *between the parallel tangents, and the common radius of the reversed curve, to find the* **central angle** *of each arc.* Fig. 60.

Let APB be the center line of the reversed curve, DG the center line between tracks,

$$AC = BC' = r, \text{ and } ACP = BC'P = \Delta_r.$$

Then

$$AD = BG = \tfrac{1}{2}p$$

and

$$\text{vers } ACP = \frac{AD}{CP}$$

or

$$\text{vers } \Delta_r = \frac{\tfrac{1}{2}p}{r} \tag{206}$$

If p and Δ_r are given, by transposing eq. (206) there results

$$r = \frac{\tfrac{1}{2}p}{\text{vers } \Delta_r} \tag{207}$$

l. *Given: the perpendicular distance* **p** *between the el tangents, and the radius and central angle of the first the reversed curve, to find the* **radius** *of the* **second arc.** 1.

APB be the center line of the reversed curve, $AC = r_1$, $= r_2$, $HB = p$, $ACP = BC'P = \Delta_r$.

w *DG* through the P.R.C. and parallel to *AH*.

$$B = p = AD + GB = CP \text{ vers } ACP + C'P \text{ vers } BC'P$$

$$p = r_1 \text{ vers } \Delta_r + r_2 \text{ vers } \Delta_r$$

which

$$r_1 + r_2 = \frac{p}{\text{vers } \Delta_r} \qquad (208)$$

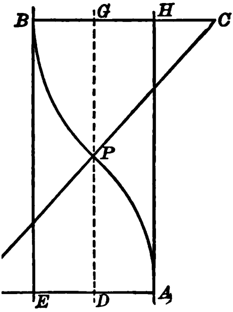

FIG. 60.

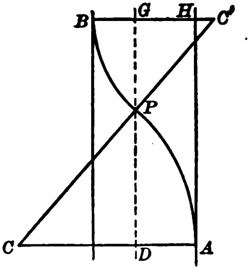

FIG. 61.

r_1, r_2 and p are given, Δ_r may be found by transposing 08), giving

$$\text{vers } \Delta_r = \frac{p}{r_1 + r_2} \qquad (209)$$

. *Given: the perpendicular distance* **p** *between parallel ts, the* **chord distance d,** *between the* P.C. *and the and the radius,* $\mathbf{r}_1$, *of the first arc of the reversed curve, d the radius,* $\mathbf{r}_2$, *of the second arc.* Fig. 62.

APB be the center line of the reversed curve,

$$AB = d, \; AC = r_1, \; BC' = r_2$$

It may be proved that the line AB passes through P, the point of reverse curve. By drawing a line $C'L$ parallel to BA and erecting a perpendicular to it, a triangle KCL is formed which will be similar to the triangle ABH.

Then

$$CL : LK :: AB : BH$$

But

$$CL = r_1 + r_2,\ LK = \tfrac{1}{2}AB \text{ and } BH = p$$

∴

$$(r_1 + r_2) : \tfrac{1}{2}d :: d : p$$

or

$$r_1 + r_2 = \frac{d^2}{2p} \tag{210}$$

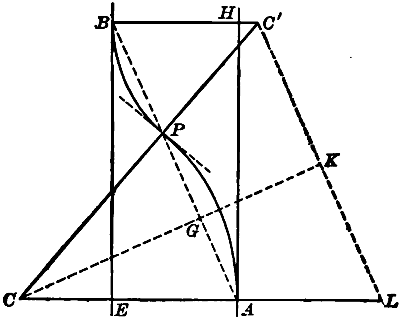

Fig. 62.

If r_1, r_2 and p are given, d may be found from eq. (210).

$$d = \sqrt{2(r_1 + r_2)p} \tag{211}$$

With equal radii, $r_1 = r_2 = r$ and eq. (210) becomes

$$r = \frac{d^2}{4p} \tag{212}$$

and eq. (211) becomes

$$d = 2\sqrt{rp} \tag{213}$$

183. *Given: the length,* **l**, *of the* **common tangent** *of a reversed curve and the* **angles of intersection** *with the diverging tangents, to find the common radius of a reversed curve connecting the diverging tangents.* Fig. 63.

Let V_1V_2 be the common tangent of length l, AV_1 and BV_2 the diverging tangents, $EV_1P = \Delta_1$, and $GV_2P = \Delta_2$ the angles of intersection.

Then

$$V_1V_2 = V_1P + V_2P$$

or

$$l = r \tan \tfrac{1}{2}\Delta_1 + r \tan \tfrac{1}{2}\Delta_2$$

whence

$$r = \frac{l}{\tan \frac{1}{2}\Delta_1 + \tan \frac{1}{2}\Delta_2} \qquad (214)$$

Table III may be used in an approximate solution as follows: Find the tangent distances for a 1° curve with central angles of Δ_1 and Δ_2, designating them by T_1 and T_2. Then the desired degree of curve will be

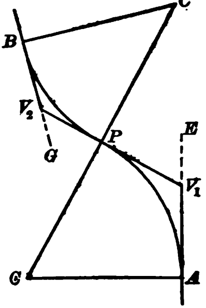

FIG. 63.

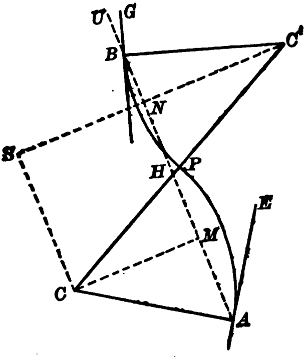

FIG. 64.

$$D = \frac{T_1 + T_2}{l} \text{ (approx.)}$$

184. *Given: diverging tangents, a line,* **AB**, *joining them, and the angles at* **A** *and* **B**, *to find the* **common radius** *of a reversed curve extending from A to B.* Fig. 64.

Let $l = AB$, EAB and UBG = the given angles A and B.

Draw CM and $C'S$ perpendicular to, and CS parallel to AB

Let $AHC = C'HB = C'CS = H$.

Then

$$C'S = CC' \sin H = 2r \sin H$$

Also

$$C'S = C'N + CM = r \cos A + r \cos B.$$

Equating, $2r \sin H = r \cos A + r \cos B$

or

$$\sin H = \tfrac{1}{2}(\cos A + \cos B)$$

Now

$$AB = l = AM + NB + CS$$

or

$$l = r \sin A + r \sin B + 2r \cos H$$

and

$$r = \frac{l}{\sin A + \sin B + 2 \cos H} \tag{215}$$

The station of the point P may be found from the degree of curve and the central angle C which equals $90° + A - H$.

185. The solution of curve problems may often be simplified by *measuring* a *certain distance*, or an *angle* and a *distance* in the *field*.

In the case of diverging tangents for reversed curves, an easier solution may sometimes be found by prolonging one arc until it is parallel to the other, thus using eq. (208) with the distance p known.

186. *Given: the* **angle of intersection** *of two diverging tangents, the* **distance** *from the* **P.C. to V.** *and the* **unequal radii** *of a reversed curve, to find the* **central angles** *of the two arcs and the* **distance from V to the P.T** Fig. 65.

Let the following be the given quantities:

AV, the given distance, A the P.C. of the curve, and $AVT = \Delta$.

Designate ACP by Δ_1, $PC'B$ by Δ_2, CA by r_1, and $C'B$ by r_2.

Continue the arc PA to the point E where it comes to a tangent parallel to VT.

Then ET is the perpendicular distance between the parallel tangents and if designated by p may be found from eq. (208).

$$ET = p = (r_1 + r_2) \text{ vers } ECP$$

Again

$$ET = EK + AS = r_1 \text{ vers } \Delta + AV \sin \Delta$$

Equating, and since $ECP = BC'P = \Delta_2$ we get,

$$(r_1 + r_2) \text{ vers } \Delta_2 = r_1 \text{ vers } \Delta + AV \sin \Delta$$

or

$$\text{vers } \Delta_2 = \frac{r_1 \text{ vers } \Delta + AV \sin \Delta}{r_1 + r_2} \tag{216}$$

$$\Delta_1 = \Delta_2 - \Delta$$

The distance $VB = VS + AK - TB$

or

$$VB = VA \cos \Delta + r_1 \sin \Delta - (r_1 + r_2) \sin \Delta_2 \tag{217}$$

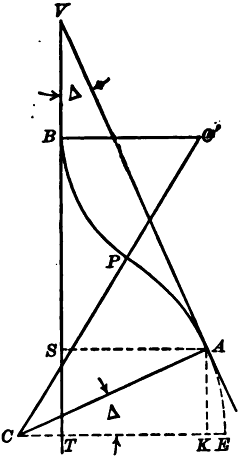

FIG. 65.

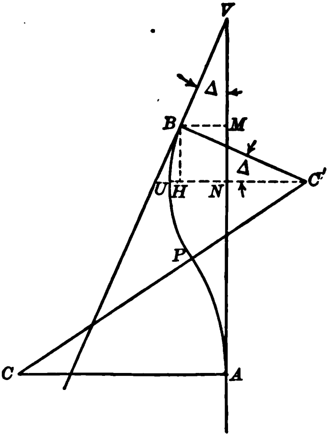

FIG. 66.

187. *Given: the* **angle of intersection** *of two diverging tangents, the* **distance** *from the* **P.T to V,** *and the* **unequal radii** *of a reversed curve, to find the* **central angles** *of the two arcs and the* **distance** *from the* **P.C. to V.** Fig. 66.

The figure is similar to that in the previous section except the arc AE is omitted and the lines $C'U$ and MB are drawn perpendicular to AV and BH perpendicular to C'U.

A tangent to the arc at the point U will be parallel to VA and from eq. (208), $NU = p = (r_1 + r_2) \text{ vers } \Delta_1$.

But

$$NU = UH + BM = r_2 \text{ vers } \Delta + BV \sin \Delta$$

$$\therefore \quad \text{vers } \Delta_1 = \frac{r_2 \text{ vers } \Delta + BV \sin \Delta}{r_1 + r_2} \tag{218}$$

and

$$\Delta_2 = \Delta_1 + \Delta$$

Also

$$VA = VM + BH + NA$$

$$= VB \cos \Delta + r_2 \sin \Delta + (r_1 + r_2) \sin \Delta_1 \tag{219}$$

CHAPTER VIII

TURNOUTS AND CROSSINGS

A. Turnouts

188. A turnout is a curved track leading from one track to another. The *switch rails* turn the train from one track to the other, and at the point where the outer rail of the turnout crosses the rail of the main track a *frog* is introduced which allows the flanges of the wheels to pass the main rail. At points opposite the frog, guard rails are placed, their object being to prevent the wheel flanges from bearing against the frog point and also to keep them from being turned to the wrong side of the point.

The *stub switch*, Fig. 67, is a form which is not much used at the present time. The switch rails are common to both tracks. One end of each rail is free and can be shifted from one track to the other as required. The free end of the rail is called the *point or toe of switch*. The tangent point at A is called the *heel of switch*, and the distance, AD, is the *length of switch*. The switch rail should be several feet longer than AD or BG, and the excess be spiked down in the line of the main track back of A or B. Then if the switch rails are thrown over to meet the rails of the turnout they will be sprung into arcs coinciding with those of the turnout, provided that they are made of proper length. The distance DK through which the point of the rail moves is called the *throw* of the switch. It varies from 4½ to 6 inches.

The *split switch*, Fig. 68, is the form most commonly used at the present time. In this form, one rail of the main track and the inner rail of the turnout are continuous. The outer switch rail when set for the turnout makes an abrupt angle with the main track. Both switch rails are planed at one end to a wedge point ¼ of an inch in thickness. To prevent the inner switch rail from projecting inside the gauge rail when set for the main track, the inner stock rail of the turnout is bent at a point slightly back of the switch point. Fig. 68 shows the switch set for the turnout.

The switch rails are fastened together by two or more tie rods, the first rod being connected either to the switch stand, or to a rod extending from the interlocking plant. The switch rails are free to move over their entire lengths, but are fastened at the *heel of switch*, points *J* and *K*, and hinge about these points. The distance gauge to gauge at the heel of the switch should be enough to allow for an angle splice and the insertion of a spike. This distance is about 6¼ inches. The lengths of switch rails recommended by the American Railway Eng. Assoc. range from 11 to 33 feet.

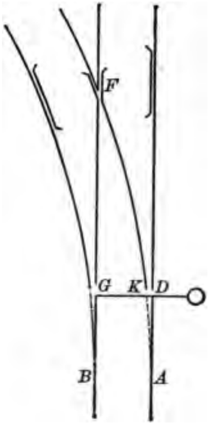

Fig. 67.

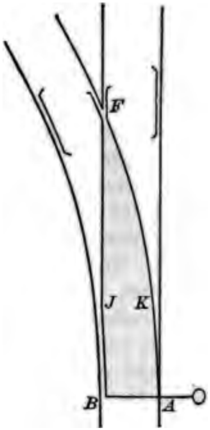

Fig. 68.

189. The Frog. Two general types of frogs are used, the *rigid* frog and the *spring* frog. The parts of the rigid frog are shown in Fig. 69. In the rigid frog, the wing rails are both fastened securely to the main part of the frog, with sufficient clearance for the flanges of the wheel. The spring frog is used where the bulk of traffic is on the main track. The main flangeway is always open, but the other *closed to afford* a continuous bearing for wheels on the main track. The movable wing is held against the point by a spring, but is pushed aside by the flange of each wheel passing the frog on the turnout. Frogs may be designated by their angles, but it is customary to designate them by numbers expressing the ratio of the bisecting line *FC* of the tongue to the base line, *ab*, Fig. 70. Observe that *F* is at the intersection of the edges produced, and not at the blunt point of the tongue. The point of intersection of the two lines is called the *theoretical* point and the blunt is the *actual* point. The actual point is usually ½ inch thick.

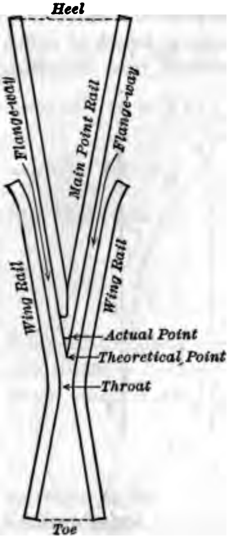

FIG. 69.

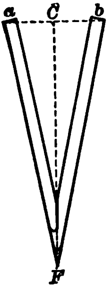

FIG. 70.

In the triangle *aFC*,

$$\frac{FC}{aC} = \cot \tfrac{1}{2} aFb$$

and if we let n = the number of the frog, and F = the frog angle, then

$$n = \frac{FC}{ab} = \frac{FC}{2aC} = \tfrac{1}{2} \cot \tfrac{1}{2} F$$

If t denotes the thickness at the actual point, then the distance between the theoretical and actual points $= nt$.

190. In computing a turnout, both switch rail and frog may be considered curved; the switch rail may be considered straight and the frog rail curved; or both switch rail and frog may be straight.

191. Split Switch. In the split switch both the switch rails and the frog are straight. A circular curve called the *lead curve* joins the two and is tangent to them.

Given: a straight track of gauge, g, length of switch rail l, frog angle F, and number n, distance from theoretical point to toe of frog f, distance gauge to gauge at heel of switch h, thickness of frog point t, and of switch point w. To find the lead *from point of switch to the theoretical frog point and also to the actual frog point; the radius of the lead curve* **r** *and the* **length of the rails between heel of switch and toe of frog.** Fig. 71.

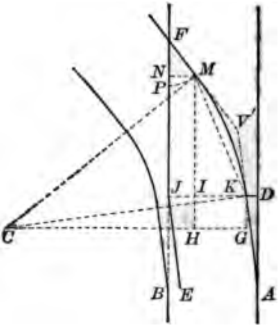

FIG. 71.

Let AK and EJ be the switch rails, DK the distance gauge to gauge at heel of switch, h, and S the switch angle DAK.

Draw the construction lines shown in the figure.

$$\sin S = \frac{h - w}{l} \tag{221}$$

The angle $V'MI = F$, and $V'MK = \tfrac{1}{2}(F - S)$

$$KMI = F - \tfrac{1}{2}(F - S) = \tfrac{1}{2}(F + S)$$

Now

$$KI = DJ - DK - MN = g - h - f \sin F$$

and

$$IM = KI \cot KMI = (g - h - f \sin F) \cot \tfrac{1}{2}(F + S)$$

Then the theoretical lead $= L_t =$ distance from the switch point to theoretical frog point $= BF = BJ + IM + NF$ or

$$L_t = l + (g - h - f \sin F) \cot \tfrac{1}{2}(F + S) + f \cos F \qquad (222)$$

and the actual lead $= L_a$ is

$$L_a = l + (g - h - f \sin F) \cot \tfrac{1}{2}(F + S) + f \cos F + nt \qquad (223)$$

One value of $GH (= KI)$ has just been found. A second value is,

$$GH = GC - HC = (r + \tfrac{1}{2}g) \cos S - (r + \tfrac{1}{2}g) \cos F.$$

Equating these two values and solving for r

$$(r + \tfrac{1}{2}g) = \frac{g - h - f \sin F}{\cos S - \cos F} = \frac{g - h - f \sin F}{2 \sin \frac{1}{2}(F - S) \sin \frac{1}{2}(F + S)} \qquad (224)$$

On FB lay off the distance $FP = FM = f$.

Then the distance between the heel of switch and toe of frog on main track $= JP = BF - BJ - PF$

or

$$JP = L_a - l - f - nt \qquad (225)$$

This equation is independent of the radius and may be used to check a second equation as follows:

$$JP = HM - IH - PN$$

or

$$JP = (r + \tfrac{1}{2}g) \sin F - (r + \tfrac{1}{2}g) \sin S - f \operatorname{vers} F \qquad (226)$$

The length of the curved rail KM is found by the formula

$$KM = .017453\ (r + \tfrac{1}{2}g)\ (F - S) \qquad (227)$$

in which the angle or arc $(F - S)$ is expressed in degrees.

192. *Tables for Turnouts.* The leads computed by eqs. (222) and (223) are called "theoretical" leads. In order to reduce the cutting and loss of rails, the American Railway Engineering Association has adopted certain combinations of switches and frogs. Calculations have been these combinations and they are given in Tables XXIIA and XXIIB. The tangent adjacent to the heel of switch is lengthened in some cases, and in others, that adjacent to the toe of the frog.

The effect of lengthening the tangent adjacent to the heel of switch is to *lengthen* the lead, while that of extending the tangent adjacent to the toe of the frog is to *shorten* the lead.

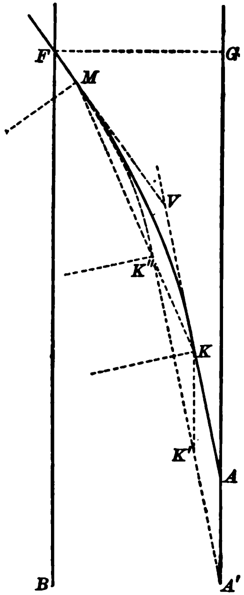

Fig. 72.

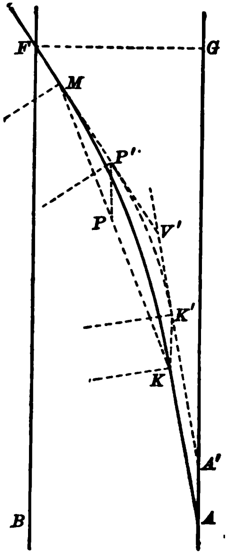

Fig. 73.

In the next two sections there will be found the effects of these two changes on the length of the lead and on the radius of the connecting curve.

193. *Given: the theoretical lead, the* **increase in lead necessary for the practical lead** *and the data for the turnout, to find the* **length of the tangent adjacent to the heel of switch.** Fig. 72.

The other given quantities are F, S, l, g, L_t, f and h.

Let AG be the theoretical lead; $A'G$ the practical lead; $AKMF$ the original turnout; and $A'K''MF$ that for the practical lead. Designate $A'K''$ by l'. Draw $K'K$ parallel to AG and connect K and M.

The length of switch rail is the same in the two turnouts as is the distance gauge to gauge at heel of switch, consequently the central angles of the two arcs will each be equal to $(F - S)$ and the line KM must pass through the point K'' (§ 137)

$$A'A = K'K = \text{the given increase in lead}$$

$$K''K'K = S; \quad K'K''K = \tfrac{1}{2}(F - S)$$

and

$$K''KK' = 180° - (K'K''K + K''K'K) = 180° - \tfrac{1}{2}(F + S)$$

Solve the triangle $K''KK'$ and

$$K'K'' = l' - l = \frac{A'A \sin \frac{1}{2}(F + S)}{\sin \frac{1}{2}(F - S)} \tag{228}$$

The perpendicular distance from K'' to the line $K'K$ produced is $(l' - l) \sin S$ and if the numerator of eq. (224) is reduced by this value we get the radius of the new turnout curve

$$(r + \tfrac{1}{2}g) = \frac{g - h - f \sin F - (l' - l) \sin S}{2 \sin \frac{1}{2}(F - S) \sin \frac{1}{2}(F + S)} \tag{229}$$

194. *Given: the theoretical lead, the* **decrease in lead necessary for the practical lead** *and the data of the turnout, to find the* **length of the tangent adjacent to the toe of the frog.** Fig. 73.

The given quantities are the same as in § 193.

Designate FP' by f'. Now $PP' = A'A$.

Solve the triangle $MP'P$ in a similar way to that in the previous section.

$$P'M = f' - f = \frac{A'A \sin \frac{1}{2}(F + S)}{\sin \frac{1}{2}(F - S)} \tag{230}$$

Also if the numerator of eq. (224) is reduced by $(f' - f) \sin F$ it becomes $g - h - f' \sin F$ giving the radius of the new turnout curve

$$(r + \tfrac{1}{2}g) = \frac{g - h - f' \sin \mathrm{F}}{2 \sin \frac{1}{2}(F + S) \sin \frac{1}{2}(\mathrm{F} - \mathrm{S})} \tag{231}$$

195. In case of a double turnout from the same switch three frogs are required, and the switch is called a *three-throw* switch, because its points take three different positions. When split switches are used for such a combination it is advisable to have the second set of switch rails placed slightly in advance of the first set. This form is termed a *tandem* switch.

Given: the equal frog angles F and F′ of a **tandem split switch,** *the distance d from one point of switch to the other, the radius r of the two curves, and the length l of both switch rails, to find the* **angle of the crotch frog F″,** and the **crotch frog distance.** Fig. 74.

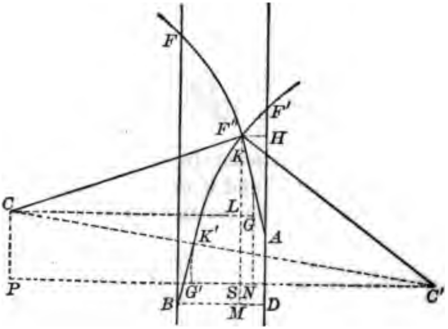

Fig. 74.

The rails of the main track frogs and the switch rails will be considered straight, while the crotch frog rails will be taken as curved.

Let AKF and $BK'F'$ be the outer rails of the double turnout, whose radii, CF'' and $C'F'' = r + \frac{1}{2}g$.

Produce each curve backward until it becomes parallel to the main track rails at the points G and G'. Draw $C'G'$ to meet CP drawn parallel to AF'. Designate the distances from G and G' to the main track rails by o, and from the figure

$$o = h - (r + \tfrac{1}{2}g) \text{ vers } S \qquad (232)$$

where h = distance gauge to gauge at heel of switch, and S = the switch angle.

Solve the right triangle CPC' for $CC'P$ and CC' where

$$CP = GN = AD = d$$

and

$$PC' = CG + C'G' - G'N$$

$$= (r + \tfrac{1}{2}g) + (r + \tfrac{1}{2}g) - (g - 2o) = 2(r+o)$$

Then in the isosceles triangle $CF''C'$

$$\cos F''CC' = \frac{\tfrac{1}{2}CC'}{CF''} = \frac{\tfrac{1}{2}CC'}{r + \tfrac{1}{2}g} \tag{233}$$

and the crotch frog $F'' = 2F''CC'$.

The crotch frog distance $DH = F''S + SM$.

Now

$$F''S = (r + \tfrac{1}{2}g) \sin F''C'S$$

and

$$SM = l - (r + \tfrac{1}{2}g) \sin S$$

$$\therefore \quad DH = (r + \tfrac{1}{2}g) \sin F''C'S + l - (r + \tfrac{1}{2}g) \sin S \tag{234}$$

The angle $F''C'S$ is the sum of $F''C'C$ and $CC'P$, which angles were obtained by solving the triangles $CC'F''$ and CPC'.

Where a stub switch is used with the crotch frog symmetrically placed with respect to F and F', the number and angle of the crotch frog are given in Table XXII.

196. Stub Switch. With the stub switch, the line from the heel of the switch to the point of frog is considered a simple curve.

Given: a straight track of gauge g, the frog angle F, the frog number n, and the throw t, to find the **lead** *of the stub switch, the radius* **r** *of the center line of the turnout curve and the length of the switch rail* **l.** Fig. 75.

Let C be the center of the turnout;

F = frog angle;

g = gauge of track;

DK = the throw of the switch;

r = the radius Ca.

Two sets of formulas may be found, the one in terms of F and the other in terms of n.

First, formulas containing **F.** From the figure,

$$AB = g = FC \text{ vers FCB}$$

or

$$g = (r + \tfrac{1}{2}g) \text{ vers F}$$

whence

$$(r + \tfrac{1}{2}g) = \frac{g}{\text{vers } F} \tag{235}$$

$$BF = L_s = AB \cot BFA = g \cot \tfrac{1}{2}F \tag{236}$$

Also

$$BF = L_s = FC \sin FCB = (r + \tfrac{1}{2}g) \sin F \tag{237}$$

From the isosceles triangle aCf

$$af = 2r \sin \tfrac{1}{2}F \tag{238}$$

Similar to eq. (235) we have

$$\text{vers } ACK = \frac{DK}{CA} = \frac{DK}{(r + \tfrac{1}{2}g)}$$

Also

$$AD = (r + \tfrac{1}{2}g) \sin ACK.$$

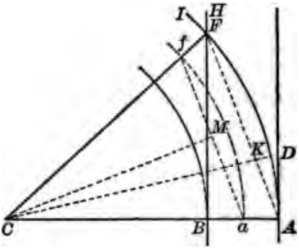

Fig. 75.

But since the inside rail has the same throw as AD, while its radius is $(r - \frac{1}{2}g)$, we may drop the $\frac{1}{2}g$, hence the length of the switch rail is

$$AD = r \sin ACK \text{ (approx.)} \tag{239}$$

Second, formulas containing **n.**

From the triangle BFA,

$$BF = L_s = AB \cot BFA = g \cot \tfrac{1}{2}F$$

But from eq. (220) $\cot \frac{1}{2}F = 2n$

$$\therefore \qquad BF = L_s = 2gn \tag{240}$$

From the triangle BFC

$$BF^2 = FC^2 - BC^2$$

or

$$BF^2 = L_s^2 = (r + \tfrac{1}{2}g)^2 - (r - \tfrac{1}{2}g)^2 = 4g^2n^2$$

whence

$$2gr = 4g^2n^2$$

or

$$r = 2gn^2 = L_s n \tag{241}$$

Draw the line *CM* bisecting *af*. Then the triangle *aCM* and *ABF* are similar, and

$$aM : aC :: AB : AF$$

or

$$\tfrac{1}{2}af : r :: g : AF$$

$$\therefore \qquad af = \frac{2gr}{AF}$$

but

$$AF = \sqrt{BA^2 + BF^2} = \sqrt{g^2 + 4g^2n^2} = g\sqrt{1 + 4n^2}$$

consequently

$$af = \frac{2r}{\sqrt{1 + 4n^2}} \tag{242}$$

From eq. (38) the throw $DK = t = \frac{AD^2}{2r}$

$$\therefore \qquad l = AD = \sqrt{2rt} \tag{243}$$

Table XXII has been calculated by the preceding formulas. This table applies only to *stub switch turnouts.*

197. The rails between the switch point and the frog point may be located in three different ways:

First, decide upon the position for the frog point and lay off the proper lead, thus locating the switch point. Place the switch rails and the frog in position and locate the connecting rails by eye.

Second, offsets may be taken from a gauge side of the main track rail to the gauge side of the turnout rail. Fig. 76 applies to a split switch. The curve *KM* is produced backward through the angle *S* where it becomes parallel to the main track rail *AD*. Divide *KM* into four parts and through each point of division draw lines perpendicular to AD.

From eq. (232)

$$VW = o = DK - (r + \tfrac{1}{2}g) \text{ vers } S = h - (r + \tfrac{1}{2}g) \text{ vers } S$$

$$\text{Angle } KCM = (F - S)$$

$$WCS = S + \tfrac{1}{4}(F - S) \qquad WCT = S + \tfrac{1}{2}(F - S)$$

$$WCU = S + \tfrac{3}{4}(F - S) \qquad WCM = S + (F - S) = F$$

Then $AD = l$ approx., and

$$VA = VD - AD = (r + \tfrac{1}{2}g) \sin S - l = q$$

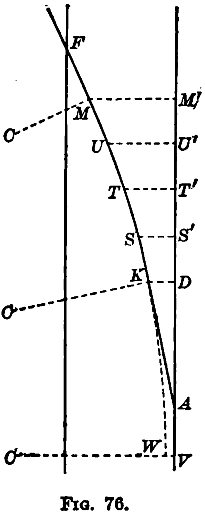

FIG. 76.

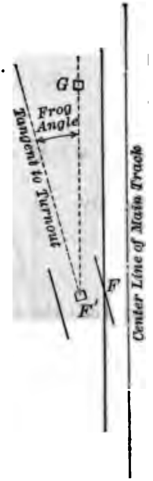

FIG. 77.

Note that V will fall *between* A and D with long switch rails.

Now

$$AS' = (r + \tfrac{1}{2}g) \sin WCS - q$$

and

$$S'S = (r + \tfrac{1}{2}g) \text{ vers } WCS + o$$

Similar expressions may be given for AT' and $T'T$, AU and $U'U$ and so on.

Table XXIIB gives the coordinates of the quarter point *different* lead curves.

With a *stub switch* the offsets may be found by the methods of §§ 119 and 120.

When a tangent is introduced beyond the heel of the switch the value of o from eq. (232) will be

$$o = h + (l' - l) \sin S - (r + \tfrac{1}{2}g) \operatorname{vers} S \qquad (232A)$$

Third, having placed the switch rails and the frog, the lead curve connecting the two may be located by taking offsets from the long chord of the curve. The length of the long chord of the outer rail of a *split* switch is deduced from Fig. 76, and is $KM = 2(r + \frac{1}{2}g) \sin \frac{1}{2}(F - S)$. The values of the offsets may be found by the methods of §§ 121 to 125. As applied to the *stub switch*, the middle-ordinate of the long chord AF, Fig. 75, is $\frac{1}{4}g$, and the ordinates at the quarter points are $\frac{3}{16}g$.

198. The track *beyond the heel of the frog* will assume one of the following forms: It may be straight, or there may be a combination of curves and tangents; it may be part of a cross-over between parallel tracks; or it may be extended to a parallel side track.

No special formulas need be derived where there is no definite connection with a cross-over or parallel side track. The method of procedure is illustrated by Fig. 77. A tangent at the frog point is located by sighting along the line $F'G$ with the angle F laid off on the proper side of zero. After the location of this tangent, the work proceeds as in any straight line or curve work.

199. Cross-overs. A cross-over is a track connecting two parallel tracks, either straight or curved. There are two usual forms, first, where the heels of the frog are connected by a tangent, and second, where they are connected by a reversed curve.

Given: the perpendicular distance **p** *between two parallel straight tracks, the gauge* **g**, *the equal frog angles* **F** *and* **F'**, *to find the* **length of tangent d,** *between the frog points.* Fig. 78.

Let AF be one turnout, and $A'F'$ the other, connected by the straight track GF'. Producing the line $F'G$ to intersect the rail NF at H, we have two right-angled triangles, GFH and $F'NH$, having the common angle at $H = F$. Let p = *the perpendicular* distance between center line main tracks, and g = the gauge. Then $GF = g$, and $F'N = (p - g)$.

$$F'G = F'H - GH = \frac{F'N}{\sin F} - GF \cot F$$

or

$$F'G = d = \frac{p - g}{\sin F} - g \cot F \qquad (244)$$

Also

$$FN = NH - FH = (p - g) \cot F - \frac{g}{\sin F} \qquad (245)$$

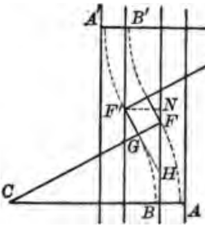

Fig. 78.

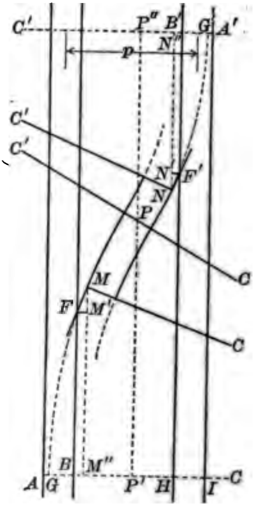

Fig. 79.

It is to be noted that d in eq. (244) is the distance from the *theoretical* frog point at F' to the point G opposite the theoretical point F. Also that the distances d and FN are independent of the shape of the rails between the frog points and switch points.

The distance between the actual frog points, measured along the main tracks will be $FN - 2nt$, where t = the width of the frog point.

200. *Given: the perpendicular distance p between the parallel straight tracks, the frog angles F and F', the length of the frog rails from point to heel k and k', the radii r_1 and r_2, of the two* *arcs of a reversed curve connecting the heels of the frogs, to find the* **central angles** *of the two arcs.* Fig. 79.

Let $CP = r_1$, $C'P = r_2$, $FM = k$, $F'N = k'$.

Produce the outer rails of the two arcs of the reversed curves backward until they become parallel to the main tracks. Also draw MM'' and NN'' perpendicular to CA and $C'A'$, and FM' and $F'N'$ perpendicular to MM'' and NN'' respectively.

Now

$$AG = o_1 = AB + FM' - GM''$$

or

$$o_1 = g + k \sin F - (r_1 + \tfrac{1}{2}g) \operatorname{vers} F \tag{246}$$

Similarly,

$$o_2 = g + k' \sin F' - (r_2 + \tfrac{1}{2}g) \operatorname{vers} F' \tag{247}$$

Consequently from eq. (209)

$$\operatorname{vers} ACP = \frac{p - o_1 - o_2}{r_1 + r_2} \tag{248}$$

Then

$$MCP = ACP - F \text{ and } NC'P = A'C'P - F'$$

When the two frogs are of the same number $F = F'$, $r_1 = r_2 = r$, and $o_1 = o_2 = o$ and eq. (249) becomes

$$\operatorname{vers} ACP = \frac{\tfrac{1}{2}p - o}{r} \tag{249}$$

and

$$MCP = NC'P = ACP - F$$

201. Turnout to a Parallel Side Track. *Given: a frog angle* **F**, *and the perpendicular distance* **p** *between the center lines of the main and side tracks, to find the radius* **r′** *of the* **curve connecting the turnout with the side track.** Fig. 80.

Let the reversing point be taken at the heel of the frog and let Q be the center of the required curve. Draw QM perpendicular to the main track. Denote the length of the frog from point to heel by k. The angle at Q will equal F.

Now

$$MS = MN - SN$$

or

$$(r' - \tfrac{1}{2}g) \operatorname{vers} F = p - g - k \sin F$$

$$\therefore \quad (r' - \tfrac{1}{2}g) = \frac{p - g - \mathrm{k} \sin \mathrm{F}}{\operatorname{vers} \mathrm{F}}$$

Also

$$FN = FT + TN = k \cos F + (r' - \tfrac{1}{2}g) \sin F \quad (251)$$

When r' is fixed by a limit, we obtain k by resolving eq. (250)

$$k = \frac{p - g - (r' - \tfrac{1}{2}g) \text{ vers } F}{\sin F}$$

202. Ladder Tracks. A *ladder track* is one that leads from the main yard track to a series of parallel tracks. The parallel tracks of a yard are called *body tracks.*

There are two usual forms of ladder tracks, first, where the ladder is straight beyond the heel of frog, and second, where a short curve is inserted beyond the heel of the frog.

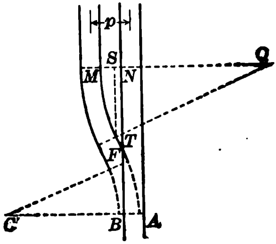

Fig. 80.

Given; a ladder track making an angle **F** *with the main track and straight beyond the heel of the frog, to find the* **distances between the theoretical frog points.** Fig. 81.

Let the perpendicular distances between the tracks be denoted by p, p', etc.

Now

$$F'G = p, \quad F''G' = p' \text{ and so on.}$$

Then

$$FF' = \frac{p}{\sin F} \text{ and } F'F'' = \frac{p'}{\sin F}$$

It is to be noted in this case that the character of the turnout curve does not affect the solution. The turnout may be of any desired form.

The distance between frog points on a ladder track should be large enough to give sufficient space for the lead, the distance from point to heel of frog, space for the angle splice at the end of the frog, and a certain extra allowance for nce between the splice and the switch including that for ecessary bending of the stock rail.

. The body tracks of a yard may be slightly lengthened serting short curves beyond the heels of the frogs of dder track.

en: the ladder and body tracks as shown in Fig. 82, *the* **s of the curve beyond the heels of the frogs,**

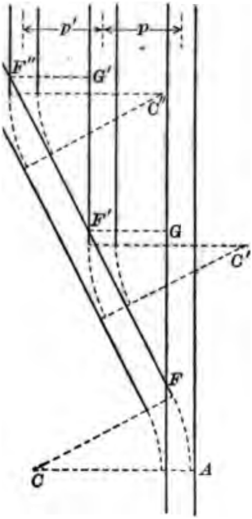

FIG. 81.

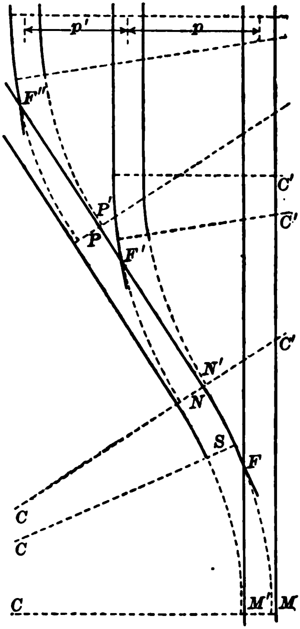

FIG. 82.

ual frogs *F*, *F'* and *F''*, *to find the* **angle MCN** *and the* **nces between the frog points.**

r denote the radius of the given curve.

duce the curves backward from the heels of the frogs. ffsets *MM'*, *NN'*, etc., are equal to *o* and may be found eq. (246).

the arc *M'SN* be moved parallel to itself until M' *coincide, then N* and *N'* will nearly coincide and reversed curve will be formed in which p and the radii are given.

Now

$$CN' = r + \tfrac{1}{2}g + o \text{ and } C'N' = r - \tfrac{1}{2}g$$

Consequently from eq. (209)

$$\text{vers } NCM = \frac{p}{CN + C'N} = \frac{p}{2r + o} \tag{252}$$

From § 202

$$NP = \frac{p'}{\sin MCN}$$

Since equal frogs are used, $NF' = PF''$. Adding the distance $F'P$ to both sides of this equation there results

$$F'F'' = NP = \frac{p'}{\sin MCN} \tag{253}$$

204. Turnouts from Curved Tracks. When a turnout leaves a main track, the parts of the frog on the *turnout may be considered straight*, but inasmuch as the parts forming sections of the main line are arcs of a curve, it seems an unnecessary refinement to differentiate between the two sides of the frog.

Consequently equations will be developed considering both switch and frog rails curved as they would be considered with a stub switch.

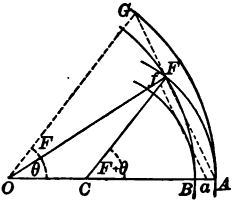

FIG. 83.

Given: a curved main track and a frog angle **F**, *to locate a turnout on the* **inside** *of the curve.* Fig. 83.

Let $R = Oa$ = radius of main track, $r = Ca$ = radius of turnout, and $F = CFO$ = the frog angle.

In the diagram draw the chord AF and produce it to intersect the outer rail at G; and draw FO and GO. Since the chords AF and AG coincide, and the radii AC and AO coincide, the chords subtend equal angles at C and O respectively, and GO is parallel to FC. (See § 137.) Hence, $FOG = CFO = F$. Let θ = the angle n the triangle FOA, $\theta = GFO - FAO = GFO - FGO$; l in the triangle GFO, $GO + FO : GO - FO ::$ tan '$FO + FGO)$: tan $\frac{1}{2}(GFO - FGO)$, or $2R : g ::$ cot : tan $\frac{1}{2}\theta$.

$$\tan \tfrac{1}{2}\theta = \frac{g}{2R} \cot \tfrac{1}{2}F = \frac{gn}{R} \tag{254}$$

the triangle CFO,

$$(r + \tfrac{1}{2}g) = (R - \tfrac{1}{2}g) \frac{\sin \theta}{\sin (F + \theta)}. \tag{255}$$

the triangle BOF;

$$BF = 2(R - \tfrac{1}{2}g) \sin \tfrac{1}{2}\theta \tag{256}$$

the triangle aCf,

$$af = 2r \sin \tfrac{1}{2}(F + \theta) \tag{257}$$

'xample.—Let $R = 1432.69$ and $F = 6° 43′ 59″$.

(254)	$\frac{1}{2}g$	2.354		log	0.371806
	$\frac{1}{2}F$		3° 21′ 59″.5	log cot	1.230440
				log	1.602246
	R	(Table I)		"	3.156151
	$\frac{1}{2}\theta$		1° 35′ 59″.8	log tan	8.446095
(255)	θ		3° 11′ 59″.6	" sin	8.746786
	$F + \theta$		9° 55′ 58″.6	" "	9.236778
					9.510008
	$R - \frac{1}{2}g$	1430.336			3.155438
	$r + \frac{1}{2}g$	462.856			2.665446
	r	460.502			
6)	2			log	0.301030
	$(R - \frac{1}{2}g)$	1430.336		"	3.155438
	$\frac{1}{2}\theta$		1° 35 59″.8	log sin	8.445924
	BF	79.872		log	1.902392
7)	$2r$	921.004		"	2.964262
	$\frac{1}{2}(F + \theta)$		4° 57′ 59″.3	log sin	8.937381
	af	79.734		log	1.901643

'he values of BF and af are found to be so nearly identical his case with those determined in case of a turnout from *traight line,* that the values given in Table X be used at once for ordinary values of R; and the *degree of curve* of the turnout in this problem is *approximately the sum* of the degree of curve of the main track and the degree

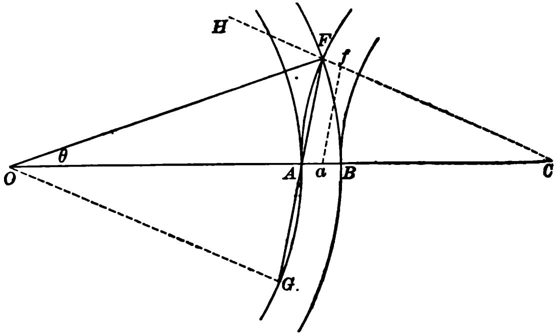

Fig. 84.

of curve given in Table XXII opposite F. Thus, in the example 4° + 8° 26′ = 12° 26′ ∴ r = 461.7 nearly.

Expressed in an equation there results

$$\text{(approx.)} \qquad d' = D + d \qquad (258)$$

where d' = the degree of curve of the new turnout, D = the degree of the main track and d = the degree of curve of a stub switch turnout from a straight track and for the same frog number.

205. Other cases may arise as shown in Figs. 84 and 85.

In Fig. 84, BF is the curved main track and AF the turnout is on the **outside** of the curve.

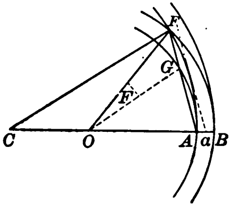

Fig. 85.

By a similar reasoning to that given in the previous section, and with the same notation it may be proved that

$$\tan \tfrac{1}{2}\theta = \frac{g}{2R} \cot \tfrac{1}{2}F = \frac{gn}{R}$$

[illegible]h *is identical* with eq. (254).

In *CFO*,

$$(r + \tfrac{1}{2}g) = (R + \tfrac{1}{2}g)\,\frac{\sin\theta}{\sin(F - \theta)}$$

In *BOF*,

$$BF = 2(R + \tfrac{1}{2}g)\sin\tfrac{1}{2}\theta$$

In *aCf*,

$$af = 2r\sin\tfrac{1}{2}(F - \theta)$$

(approx.) $$d' = d - D \tag{259}$$

When $d = D$, the turnout becomes a straight line.

In Fig. 85, the turnout AF is on the **outside** of the main track but its **center** C falls on the **same side** as O. The equation for this case is

$$(r - \tfrac{1}{2}g) = (R + \tfrac{1}{2}g)\,\frac{\sin\theta}{\sin(\theta - F)}$$

$$BF = 2(R + \tfrac{1}{2}g)\sin\tfrac{1}{2}\theta$$

$$af = 2r\sin\tfrac{1}{2}(\theta - F)$$

(approx.) $$d' = D - d \tag{260}$$

206. Split Switch Turnouts from Curved Tracks.

It may be proved in a somewhat similar manner to that outlined in the previous sections that for a certain frog number the lead for a split switch turnout going from a curved track is practically the same as the lead from a straight track of the same number. The degrees of curve are expressed approximately by eqs. (258), (259) and (260).

Tables XXIIA and XXIIB give the standard split switch data.

207. To Connect a Curved Main Track with a Parallel Siding.

Given: the perpendicular distance **p** *between the center lines of a curved main track and a parallel side track, and the frog angle* **F** *of a turnout; to find the radius* **r** *of the connecting curve, and the length* **FN**, *or* **fm**, *of the curve.* Fig. 86.

Let FN be the rail of the main track, and GM the rail of the siding, adjacent to each other; let O be the center of the main track, and Q the center of the connecting curve. Then the connecting curve will terminate at m, on the line OQ produced.

In the diagram draw MF, and produce it to intersect the rail MG at G, and join GO, FO, and FQ.

Let R = *radius of* center line of the main track; r =

radius of center line of the connecting curve; and θ = th angle FOM.

Case a.—*The siding* **outside** *the main track.* Fig. 86.

By similarity of the triangles GOM and FQM, GO i parallel to FQ, and the angle $GOF = F$; and by a proces similar to that of § 204 we have from the triangle FMO

$$\tan \tfrac{1}{2}\theta = \frac{p - g}{2R + p} \cot \tfrac{1}{2}F$$ (261

From the triangle FQO

$$r - \tfrac{1}{2}g = (R + \tfrac{1}{2}g) \frac{\sin \theta}{\sin (F + \theta)}$$ (262

$$FN = 2(R + \tfrac{1}{2}g) \sin \tfrac{1}{2}\theta$$ (263

$$fm = 2r \cdot \sin \tfrac{1}{2}(F + \theta)$$ (264

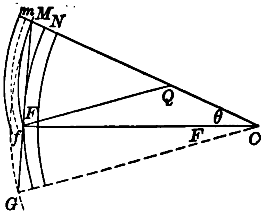

FIG. 86.

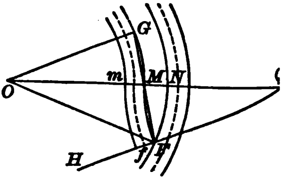

FIG. 87.

Case b.—*The siding inside the main track with the* **cente** *of the connecting curve* **outside** *the main track.* Fig. 87.

By a process entirely similar to § 204, we have

$$\tan \tfrac{1}{2}\theta = \frac{p - g}{2R - p} \cot \tfrac{1}{2}F$$ (265

$$r - \tfrac{1}{2}g = (R - \tfrac{1}{2}g) \frac{\sin \theta}{\sin (F - \theta)}$$ (266

$$FN = 2(R - \tfrac{1}{2}g) \sin \tfrac{1}{2}\theta$$ (267

$$fm = 2r \sin \tfrac{1}{2}(F - \theta)$$ (268

When $\theta = F$ in the last equations, $\sin (F - \theta) =$ (and $r - \tfrac{1}{2}g$ is infinite, and the curve FM becomes a straig line.

Case c.—*The siding inside the main track with the* **cente** *of the connecting curve* **inside** *the main track.* In this cas *θ will be greater* than F.

The resulting equations will be

$$r + \tfrac{1}{2}g = (R - \tfrac{1}{2}g)\frac{\sin \theta}{\sin (\theta - F)} \tag{269}$$

$$fm = 2r \sin \tfrac{1}{2}(\theta - F) \tag{270}$$

Eqs. (265) and (267) remained unchanged.

208. *Given: the perpendicular distance* **p** *between two parallel* **curved tracks,** *to connect them by a cross-over in the form of a* **reversed curve.** Fig. 88.

Let O be the center of the main curve, and C and C' the centers of the reversed curves. The frog rails will be considered curved throughout. The arcs of the reversed curve are produced backward as shown.

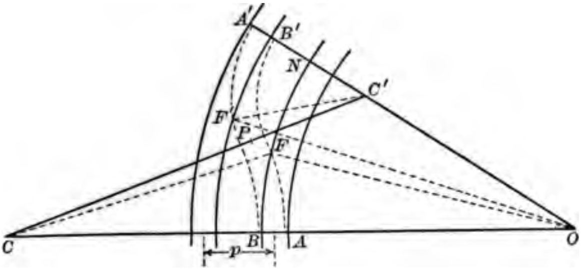

FIG. 88.

Two cases may arise: first, where the two radii of the reversed curve are assumed; and second, where the frog numbers or frog angles are assumed.

Case I. Assuming r_1 *and* r_2, the radii of the arcs beyond the frog.

Find the values of the offsets o_1 and o_2 at A and A' from the general formula

$$o = g - (r + \tfrac{1}{2}g) \text{ vers } F \tag{271}$$

This formula is derived similarly to eq. (246), but in this case, the frog is considered curved from theoretical point to heel.

Then in the triangle COC' we know all three sides; for $CO = R + r_1 + o_1$; $CC' = r_1 + r_2$; and $C'O = R + p - r_2 - o_2$.

Solve for the angles COC' and $C'CO$.

The angle $C'CO = C$, determines the length of the arc described with the radius r_1; the angle $(O + C) = CC'A'$ determines the length of the second arc, and P is the point of reversed curve.

Case II. Assume n and n', or F and F'. Take from Tables XXII, XXIIA, or XXIIB, the degree of the turnout curve from a straight track for the particular frog number.

Find from eqs. (258), (259), or (260), the degrees of the turnouts from the curved tracks. The radii corresponding to these degrees are found from Table I and the value of o_1 and o_2 from eq. (271).

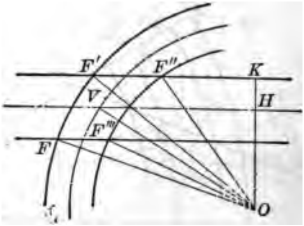

Fig. 89.

The solution from this point is the same as in Case I.

The particular advantage of this case lies in the fact that regular frogs are used, while in the other special frogs may be necessary on account of the arbitrary selection of the radii.

B. Crossings.

209. When two tracks cross, four frogs are necessary. Both tracks may be straight, one may be straight and the other curved, or both may be curved. With both tracks straight, two frog angles are supplements of the other two. In this case, right triangles are solved and no special formulas need be derived.

Given: a straight track of gauge **g** *crossing a curved track with radius* **R** *and gauge* **g'**, *and the* **angle between the center lines,** *to find the* **frog angles and the distances between the frog points.** Fig. 89.

From O, the center of the main track, draw the lines OF, OF', OF'', and OF'''; also OH perpendicular to VH.

Let g and g' be the gauges of the straight and curved tracks; $OV = R$, and angle $HVO = 90° - \Delta$.

Then

$$OH = OV \sin (90° - \Delta) = R \cos \Delta$$

$$\cos F = \frac{OH - \frac{1}{2}g}{R + \frac{1}{2}g'} \tag{272}$$

$$\cos F' = \frac{OH + \frac{1}{2}g}{R + \frac{1}{2}g'} \tag{273}$$

$$\cos F'' = \frac{OH + \frac{1}{2}g}{R - \frac{1}{2}g'} \tag{274}$$

$$\cos F''' = \frac{OH - \frac{1}{2}g}{R - \frac{1}{2}g'} \tag{275}$$

$$\begin{aligned} F'F'' &= F'K - F''K \\ &= (R + \tfrac{1}{2}g') \sin F' - (R - \tfrac{1}{2}g') \sin F'' \end{aligned} \tag{276}$$

A similar equation may be found for FF'''.

$$FF' = (R + \tfrac{1}{2}g') \text{ arc } (F - F') \tag{277}$$

in which "arc" is regarded as a function of the angle, to radius unity, and to be found in Table XX.

So also,

$$F''F''' = (R - \tfrac{1}{2}g') \text{ arc } (F''' - F'') \tag{278}$$

It is to be noted that these lengths are between the theoretical frog points. In constructing the crossing allowance should be made for the flangeways.

210. *Given: the radii* **R** *and* **R'** *of two curved tracks of gauges* **g** *and* **g'** *which cross at* **V** *at an angle* Δ, *to find the* **frog angles** *and the* **length of the curved rails.** Fig. 90.

Let $OV = R$, $O'V = R'$, and $OVO' = \Delta$.

Solve the triangle OVO' for OO' having given two sides and an included angle. The triangle OF_1O' may be solved for F_1, and the angles F_1OO' and $F_1O'O$, having given $OF_1 = R - \frac{1}{2}g$, $O'F_1 = R' + \frac{1}{2}g'$, and OO'.

Similarly with the triangles OF_2O', OF_3O' and OF_4O'.

Then the angle

$$F_1OF_2 = F_1OO' - F_2OO'$$

and

$$F_1F_2 = (R - \tfrac{1}{2}g) \text{ arc } F_1OF_2.$$

The other three lengths may be calculated in a similar way.

211. *Given: two straight tracks crossing at an angle* Δ, *two equal frogs* **F** *and* **F′**, *and the radius* **R** *of the simple curve connecting the heels of the frogs, to find the* **distance from the center of the crossing to points opposite the theoretical frog points.** Fig. 91.

Let O be the center of the connecting curve. Designate the intersection of the inside straight rails by X. Produce the connecting curves backward as shown.

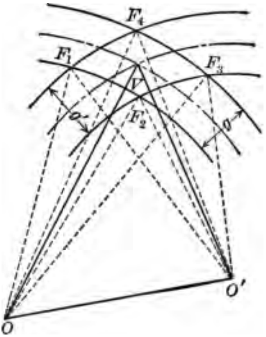

FIG. 90.

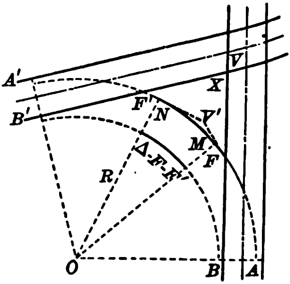

FIG. 91.

The offsets, o, at B and B' may be found from eq. (246). The central angle $MON = \Delta - F - F' = \Delta - 2F$.

Now

$$OB = OB' = R + o - \tfrac{1}{2}g$$

and

$$XB = XB' = (R + o - \tfrac{1}{2}g) \tan \tfrac{1}{2}\Delta$$

From the figure,

$$BF = B'F' = (R + \tfrac{1}{2}g) \sin F - k \cos F.$$

Then

$$XF = XF' = XB - BF.$$

For the center line distance from V to points opposite F and F', add $\tfrac{1}{2}g \tan \tfrac{1}{2}\Delta$ to each.

nt should be subtracted from each to locate the actual frog points.

he length of the arc $MN = (R + \tfrac{1}{2}g)$ arc $(\Delta - 2F)$.

212. *Given: two straight tracks crossing at an angle* Δ, *and the location of one frog, to connect them by a turnout in the form of a* **reversed curve.** Fig. 92.

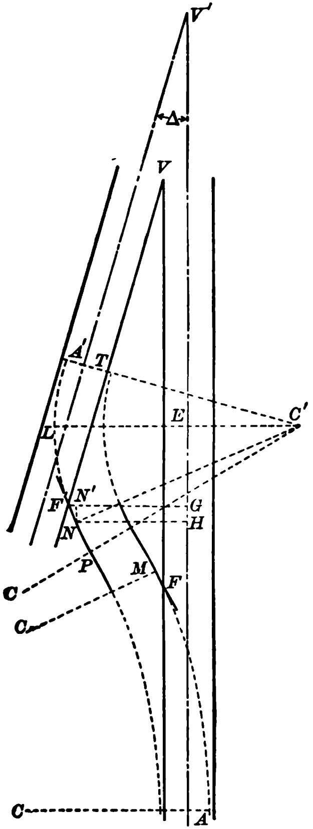

FIG. 92.

Let F and F' be the frog angles, k and k' the lengths of the frogs from points to heels. Also $C'N = R_2 + \frac{1}{2}g$, and $CM = R_1 + \frac{1}{2}g$.

The distance $F'V$ *is given.*

Produce the arcs of the reversed curve backward until they become parallel to the main tracks. Draw the other construction lines as shown. Then

$$F'G = F'V \sin \Delta + \tfrac{1}{2}g$$

$$NF'N' = 180^\circ - (90^\circ - \Delta) - F' = 90^\circ - (F' - \Delta)$$

Now

$$F'N' = F'N \cos NF'N' = k' \sin (F' - \Delta)$$

and

$$NN' = k' \cos (F' - \Delta)$$

$$NH = F'G - F'N' = F'V \sin \Delta + \tfrac{1}{2}g - k' \sin (F' - \Delta)$$

Also

$$\begin{aligned} LE &= NH + NC' \text{ vers } NC'L \\ &= NH + (R_2 + \tfrac{1}{2}g) \text{ vers } (F' - \Delta) \\ &= F'V \sin \Delta + \tfrac{1}{2}g - k' \sin (F' - \Delta) + (R_2 + \tfrac{1}{2}g) \\ &\qquad \text{vers } (F' - \Delta) \end{aligned}$$

$$GE = HE - NN'$$

or

$$GE = (R_2 + \tfrac{1}{2}g) \sin (F' - \Delta) - k' \cos (F' - \Delta) \qquad (279)$$

Now $LE - (\tfrac{1}{2}g + o_1)$ will be the perpendicular distance p between parallel tracks; o_1 is found from eq. (246).

$\therefore$ from eq. (209)

$$\text{vers } ACP = \frac{p}{R_1 + R_2}$$

Then

$$MCP = ACP - F \text{ and } PC'N = PC'L - (F' - \Delta)$$

$EA = (R_1 + R_2) \sin ACP$ and the distance from G to the point opposite F is

$$EA - EG - [(R_1 + \tfrac{1}{2}g) \sin \; F - k \cos F].$$

Since the central angles of the arcs have been found, their lengths may be obtained. The position of the frog F is fixed by its distance along the center line from the point G.

213. At the crossing of two tracks, traffic may be switched from one track to the other by a combination crossing called a **slip switch.** The switches and lead rails are entirely included between the main frogs. A great saving of room is gained over other forms of connections, but on account of the small distance between the extreme frog points, the gle between the tracks must be slight.

: the angle at which two straight tracks cross and the data switches and frogs, to find the distances along the curved veen frog points for a **slip switch crossing,** *and the f the curve connecting the heels of the switches.* Fig. 93. $K = BJ =$ the length of the switch rail, l, and DK = the distance gauge to gauge at heel of switch h.

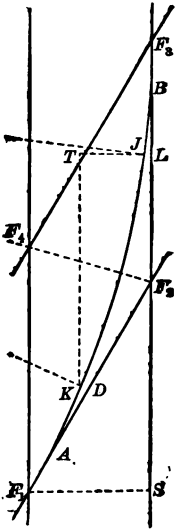

Fig. 93.

distances F_1A and F_3B are governed by the clearance ry from frog point to switch point as mentioned in

distances between successive theoretical frog points the same and are expressed by

$$F_1F_2 = F_2F_3 = F_3F_4 = F_4F_1 = \frac{g}{\sin F} \tag{280}$$

he point F_2 and F_4 the theoretical and actual points e.

direct distance between theoretical frog points F_1 is

$$F_1F_3 = \frac{g}{\sin \frac{1}{2}F}$$

Similar to the solution given in § 191, two expres
for JT may be found which are

$$JT = g - h - F_1A \sin F - l \sin (F - S)$$

and

$$JT = (R + \tfrac{1}{2}g) \cos S - (R + \tfrac{1}{2}g) \cos (F - S)$$

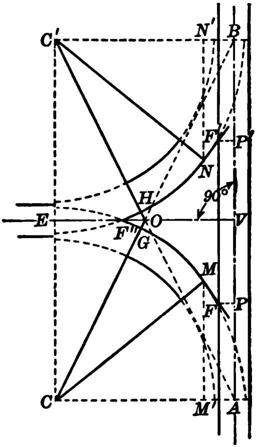

Fig. 94.

Equating these two values and solving for R we obta

$$R + \tfrac{1}{2}g = \frac{g - h - F_1A \sin F - l \sin (F - S)}{\cos S - \cos (F - S)}$$

The length of the outer curve is

$$KJ = (R + \tfrac{1}{2}g) \text{ arc } (F - 2S)$$

214. *Given: a straight track, the frog numbers and tu data, to locate a symmetrical* **Y track.** Fig. 94.

Let CM and $C'N = R + \tfrac{1}{2}g$ = the radii of the outer of the curves connecting the heels of the frogs.

Draw CA and $C'B$ perpendicular to the straight t MM' and NN' perpendicular to CA and $C'B$. Draw other construction lines as shown.

Then

$$CA = CM' + M'A = (R + \tfrac{1}{2}g) \cos F + \tfrac{1}{2}g + k \sin$$

$$GO = k' \tan \tfrac{1}{2}F''$$

and $$CO = (R + \tfrac{1}{2}g) + k' \tan \tfrac{1}{2}F''$$
$$MCO = 90° - F - \tfrac{1}{2}F''$$

The solution depends on solving several triangles.

First, ACO for AO and angle CAO, knowing two sides and the included angle; second, COE for OE. knowing CO

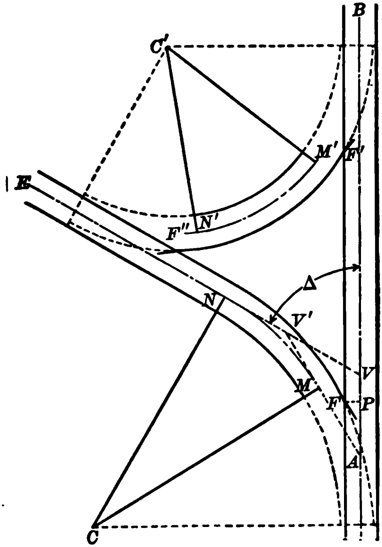

FIG. 95.

and $ECO = \tfrac{1}{2}F''$; third, AVO for VA, knowing AO and $VO = CA - OE$.

Finally
$$VP = VA - PA = VA - (R + \tfrac{1}{2}g) \sin F + k \cos F$$
and
$$VF'' = VO + OF'' = VO + k' \sec \tfrac{1}{2}F''$$

Since all the frog points are located with respect to V, the problem is solved.

215. *Given the frog angles for a* **Y between two diverging straight tracks,** *one curve being tangent to the heel of a frog in each of the straight tracks, and the second being tan* *the center line of the other, to find the* **position of the frogs.** Fig. 95.

Let AB and NE be the center lines of the given straight tracks intersecting at V with an angle Δ, MN and $M'N'$ be the connecting curves.

Produce the line AM, a tangent to the curve, to V' where it meets EN produced.

If a line FA were drawn it would bisect the angle F. Then $PA = \frac{1}{2}g \cot \frac{1}{2}F = gn$.

$$AM = gn + k \text{ and } AV' = gn + k + R \tan \tfrac{1}{2}(\Delta - F)$$

In the triangle $AV'V$

$$AV : AV' :: \sin(\Delta - F) : \sin \Delta$$

or

$$AV = \frac{AV' \sin(\Delta - F)}{\sin \Delta}$$

$$VP = VA - PA = VA - gn$$

This equation locates the point P which is opposite the frog point F. The positions of F' and F'' are located in the manner outlined in § 211.

CHAPTER IX

THE SPIRAL CURVE

216. In the early years of railroad building it was considered quite sufficient that the curves should be circles and the straight lines truly tangent to the curves. But as train speeds were increased it became necessary to introduce a curve of variable radius between the tangent and circle for two reasons: *First,* to avoid the lateral shock produced at the tangent point either on entering or leaving the circle, and *second,* to permit an elevation of the outer rail which might be everywhere proportional to the degree of curve. See Chapter XVII for derivation of formula for elevation of the outer rail.

A car running at high speed on a straight track is suddenly forced aside and takes up a circular motion on striking a curve, and when upon the curve the car body continues to revolve horizontally, like a huge bar suspended at its center of gravity, until its revolution is suddenly arrested by another piece of straight track. In either case a shock is produced deleterious both to track and rolling stock. By introducing a short curve of variable radius the transition is made easy and almost insensible.

The spiral curve here described fully meets the above requirements. It not only blends with the tangent at one end and with the circle at the other, but it also affords sufficient distance between the two for the gradual elevation of the outer rail. In shape it conforms very nearly to the cubic parabola with the advantage of requiring less track near the tangent point. The first radius is amply long without being infinite. The spiral curve is constructed upon a series of equal chords, and the angle subtended by the first chord is made the common difference for the angles subtended by the succeeding chords. It is a multi-compound curve in which the degree of curve progresses in arithmetical ratio from chord to chord.

217. Let the chord length be 100 feet and the central angles be 10′, 20′, 30′, etc., subtended by these chords. Then these numbers represent the degrees of curve on the several chords, and their sum the total spiral angle up to any specified point from the tangent point *S*. The inclination to the tangent of any one of these chords is evidently equal to half the angle it subtends added to the total preceding central angle. Thus we have, if *n* be the serial number of chord, and *s* the spiral angle:

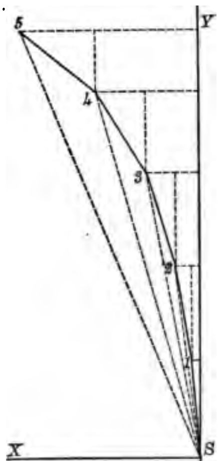

Fig. 96.

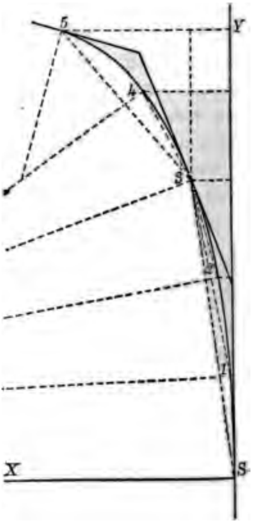

Fig. 97.

n	1	2	3	4	5	etc.
sub.	10′	20′	30′	40′	50′	etc.
s	10′	30′	1° 00′	1° 40′	2° 30′	etc.
inclination	5′	20′	45′	1° 20′	2° 05′	etc.

Thus we obtain the first four columns of Table XXXIV.

Taking the tangent as a meridian, the inclination of a ord *becomes* its bearing, from which its latitude, or 100 cos incl., and departure, or 100 sin incl., may be quickly computed. Taking the tangent point S as an origin, and calling x and y the coordinates of the several chord-points, the continuous summation of latitudes gives values of y and of departures gives values of x. These are all tabulated in Table XXXIV.

218. Spiral Deflections. Fig. 96. With the transit at S the deflection i from the tangent to any other chord point is found by the formula

$$\tan i = \frac{x}{y} \tag{283}$$

With the transit at any chord point, n, to find the deflection from the local tangent through n to any other chord point: observe, first, that for the *adjacent point*, whether forward or backward, the deflection is one half the angle subtended by the adjacent chord; thus Fig. 97, with transit at point (3) the deflection to (4) is 20′ and to point (2) it is 15′. For more distant forward points, draw long chords to them from n and find the angle a that such long chord makes with the main tangent, and deduct the angle between the main and local tangents; the difference is the value of i required. The angle a is found from

$$\tan a = \frac{x - x'}{y - y'} \tag{284}$$

in which x, y are the coordinates of the point observed and x', y' of the position of transit. And

$$i = a - s \tag{285}$$

Thus, with transit at (3) we have for point (5)

$$\tan a = \frac{7.998 \;-\; 2.036}{499.896 - 299.989} = \frac{5.962}{199.907} = .029825$$

and

$$a = 1^\circ\ 42'\ 30''$$

Since for (3)

$$s = 1^\circ$$

$$i = 0^\circ\ 42'\ 30''$$

The angle subtended by a long chord is equal to the difference of the values of s for the extremities of the chord; it is also equal to the sum of the deflections made at either *end of the long chord* to find the other. Hence, knowing the central angle and forward deflection along any long chord, we find by subtraction the backward deflection along the same chord. Thus, with transit at (3) to find (1), since $s' - s = 50'$ and the forward deflection from (1) is 22′ 30″, the difference, or $27'\ 30'' = i =$ the deflection required.

In this manner the entire Deflection Table XXXV has been calculated, and since the Spiral is invariable in form all its angles are constant and the deflections given are available in every case that can occur in practice.

219. To adapt the Spiral to practical requirements *it is only necessary to draw the figure to a* **different scale.** All its dimensions remain proportional to each other including the radii of the arcs composing the Spiral. The chord length assumed at 100 feet is now to be given smaller values ranging from 10 feet to 50 feet, and all other parts are calculated accordingly, varying directly as the chord length, while the degree of curve varies inversely, or nearly so. Table XXXVI furnishes exact values of the degree of curve, D_s, length of Spiral, nc, and values of the coordinates at each point for a variety of chord-lengths. Among these Spirals may always be found one or more that will be well adapted to the case in hand.

Only so many chords of a spiral will be used as will lead up to the required degree of curve which is to follow. The number n should be such that the degree of curve on $(n + 1)$ will equal, as nearly as may be, the required degree of curve. If the length of spiral, nc, is not satisfactory for any reason, another selection may be made from the Table under another chord length. The diagram shown in Table XXXIII gives the recommendations of the Am. Ry. Eng. Assoc. for the proper length of spirals. The basis for this diagram is the increase per second of the elevation of the outer rail.

220. To find the spiral long chord. SL, and the Spiral tangents, SE, LE, Fig. 98.

Let L be the terminal point of the spiral, x, y, the coordinates of L, i the deflection ESL and s the central angle YEL.

Then from the figure,

$$SL = \frac{y}{\cos i} \quad \text{or} \quad SL = \frac{x}{\sin i} \qquad (286)$$

To find the spiral tangents; in the triangle LEY,

$$LE = \frac{x}{\sin s} \quad \text{and} \quad SE = y - x \cot s \qquad (287)$$

To find any other spiral long chord, as KL, and the spiral tangents, KE', LE'; Let s' be the central angle for K, and i' the deflection at K for KL. Then from the figure

$$KL = \frac{KN}{\cos LKN} = \frac{y - y'}{\cos (s' + i')} \qquad (288)$$

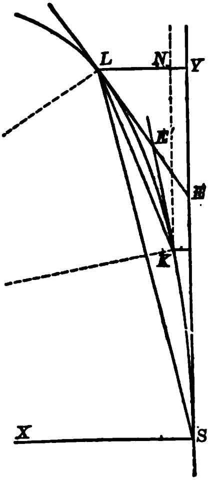

FIG. 98.

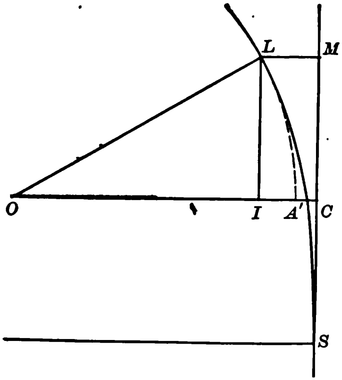

FIG. 99.

Take values of y and y' from Table XXXVI; values of s' and i' from Table XXXV.

In the triangle KLE', since $KE'E = (s - s')$,

$$LE' = \frac{KL \sin i'}{\sin (s - s')}; \quad KE' = \frac{KL \sin i}{\sin (s - s')} \qquad (289)$$

Values of Spiral long chords and tangents are tabulated in Table XXXVIII.

221. With a spiral terminating at L, if the circular arc upon the following chord length were produced backward *from L through* the angle s it would terminate at A' a line parallel to the main tangent, the perpendicular distance p, between the two being $LM - IA'$ or

$$p = x - R' \operatorname{vers} s \tag{290}$$

in which R' is the radius of the spiral arc $(n + 1)$.

Also

$$q = SM - LI = y - R' \sin s \tag{291}$$

We thus have q and p as the coordinates of the point A' which are often convenient either in the field or the office. Values of p are tabulated in Table XXXVIII. But if the radius of the curve beyond L differs from that of the spiral arc $(n + 1)$, these values of p will not apply to it and must be computed. (Compare p in Tables XXXVIII and XXXIX.)

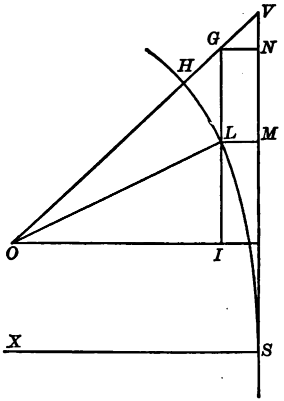

FIG. 100 .

222. Combination of Curve and Spiral. Fig. 100. *Given: A circular curve with equal spirals joining two tangents, to find* **the tangent distance,** $T_s = VS$.

Let SL be one spiral, and LH one half of the curve with its center at O. Join OL and OV, and through L draw GI parallel to the tangent and GN, LM, perpendicular to it. Then

$$IOL = s,\ IOV = \tfrac{1}{2}\Delta,\ OL = R',\ SM = y,\ LM = x$$

$$SV = SM + NV + MN$$

$$MN = GL = OL\frac{\sin LOG}{\sin OGI} = R'\,\frac{\sin(\frac{1}{2}\Delta - s)}{\cos\frac{1}{2}\Delta}$$

Hence

$$T_s = y + x\tan\tfrac{1}{2}\Delta + R'\,\frac{\sin(\frac{1}{2}\Delta - s)}{\cos\frac{1}{2}\Delta} \qquad (292)$$

Example.—Total angle 42°, Degree of curve 7° 20′, Spiral, 10 chords of 24 feet each. What is the Tangent distance?

Ans. $T_s = 416.24$.

For a small change in R' but using the same spiral, what will be the change in T_s? If in eq. (292) we give R' two values in succession and subtract, we shall have

$$\text{diff. } T_s = \text{diff. } R'\,\frac{\sin(\frac{1}{2}\Delta - s)}{\cos\frac{1}{2}\Delta} \qquad (293)$$

When selecting a curve with spirals to suit certain tangents use the following Approx.

$$T_s = R'\tan\tfrac{1}{2}\Delta + \tfrac{1}{2}nc \qquad (294)$$

or, to the tangent distance for a simple curve add one half the length of an appropriate spiral; the sum will be the approximate distance required. When a satisfactory selection has been made compute the exact T_s by eq. (292).

223. *Given: A circular curve with equal spirals, joining two tangents,* **to find the external distance,** $VH = E_s$. Fig. 100.

In the figure

$$VH = VG + GO - OH$$

$$E_s = \frac{x}{\cos\frac{1}{2}\Delta} + R'\,\frac{\cos s}{\cos\frac{1}{2}\Delta} - R'$$

$$E_s = \frac{x + R'(\cos s - \cos\frac{1}{2}\Delta)}{\cos\frac{1}{2}\Delta} \qquad (295)$$

For a small change in R', but using the same spiral, the corresponding change in E_s will be

$$\text{diff. } E_s = \text{diff. } R'\,\frac{\cos s - \cos\frac{1}{2}\Delta}{\cos\frac{1}{2}\Delta} \qquad (296)$$

Example.—Total angle 42°, Degree of curve 7° 20′, Spiral 10 chords of 24 feet each. What is the External distance? *Eq. (295).*

Ans. $E_s = 59.298$.

Example.—Changing the above degree of curve to 7° 30′ will make what change in the value of E_s? (diff. $R' = 17.351$). Eq. (296). *Ans.* diff $E_s = 0.997$.

Hence new value of $E_s = 58.301$.

For a small change in c, the chord length (n and therefore s being constant), and with the same radius as before, we have from eq. (295)

$$\text{diff. } E_s = \frac{\text{diff. } x}{\cos \frac{1}{2}\Delta} \tag{297}$$

The change in c must not be so great as to make the last degree of curve of the spiral incompatible with the main curve.

Example.—Changing the chord length to 26 feet in the above example will make what change in the value of E_s? (diff. $x = 1.118$) *Ans.* diff. $E_s = 1.197$.

New value of $E_s = 60.495$.

224. *With E_s unchanged and the angles Δ and s the same, it is required to find* **the change in R' required by a change in x in order to close on the same tangents.**

Solving eq. (295) for R' we have

$$R' = \frac{E_s \cos \frac{1}{2}\Delta - x}{\cos s - \cos \frac{1}{2}\Delta}$$

in which, by giving to x any two values and subtracting one result from the other we derive

$$\text{diff. } R' = \frac{-\text{diff. } x}{\cos s - \cos \frac{1}{2}\Delta} \tag{298}$$

The minus sign shows that R' decreases as x increases and *vice versa.*

The new value of x is taken from the Table for the same value of n as before, and such that the new spiral and resulting curve shall be consistent with each other.

Example.—Let $D' = 7° 20'$, $\Delta = 42°$, $s = 9° 10'$, $n = 10$, $c = 24$.

Select $n = 10$, $c = 26$. Then diff. $x = -1.118$ and diff. $R' = 20.84$. *Ans.*

R', $781.84 + 20.84 = 802.68$, say 7° 09′.

Note that with new value of x goes a new value of y.

[illegible]25. *Given: A simple curve, to replace it by another with* [illegible]*als on the same ground and of* **same length,** *as nearly* [illegible]*y be. Fig. 101.*

Let AH be one half the given curve with center at O, $H'L$ one half the new curve with center at O', and SL its spiral, $LM = x$, $SM = y$, $HH' = h$, the radial offset, $CA' = p$, the clearance of the curve produced. Then

$$ON = AO - NF - FA = R - R' \cos s - x$$

Also

$$ON = OO' \cos \tfrac{1}{2}\Delta = (R + h - R') \cos \tfrac{1}{2}\Delta$$

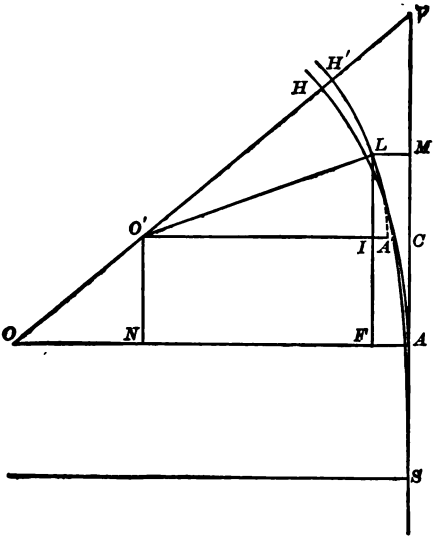

FIG. 101.

whence

$$R' (\cos s - \cos \tfrac{1}{2}\Delta) = R \operatorname{vers} \tfrac{1}{2}\Delta - x - h \cos \tfrac{1}{2}\Delta$$

and since

$$(\cos s - \cos \tfrac{1}{2}\Delta) = (\operatorname{vers} \tfrac{1}{2}\Delta - \operatorname{vers} s)$$

$$h \cos \tfrac{1}{2}\Delta = (R - R') \operatorname{vers} \tfrac{1}{2}\Delta - (x - R' \operatorname{vers} s) \qquad (299)$$

The last term is the expression for p, whence

$$(R - R') \operatorname{vers} \tfrac{1}{2}\Delta = h \cos \tfrac{1}{2}\Delta + p \qquad (300)$$

and

$$p = (R - R') \operatorname{vers} \tfrac{1}{2}\Delta - h \cos \tfrac{1}{2}\Delta$$

From the figure,

$$AS = SM - MC - CA$$

$$d = y - R' \sin s - (R - R' + h) \sin \tfrac{1}{2}\Delta \qquad (301)$$

or

$$d = q - (R - R' + h) \sin \tfrac{1}{2}\Delta$$

In view of the probable value of D' select a suitable spiral, and with the tabular value of p and any desired small value of h solve eq. (300) for $(R - R')$ whence the approximate value of R' is known. From the table of Radii correct R' to the nearest minute, and with this value of R' find h by eq. (299) and d by eq. (301). The last term of eq. (299) gives the correct value of p. Length, original, $d + \tfrac{1}{2}L$; new with spiral, $nc + \tfrac{1}{2}L'$.

If desirable a comparison of lengths may be made with the approximate value of $(R - R')$ before finally fixing on R'.

Example.—Given: D, 6° 00′; Δ, 50° 12′; select spiral n 9, c 26, s 7° 30′.

Assume h 1 foot and p (from table) 3.120; then, approx. $(R - R') = 42.65$; but adopt R' for 6° 16′; and find, eq. (299), $h = 0.991$, $p = 2.938$, $q = 114.179$, $d = 96.529$. Lengths, original, 514.86; new, 514.85.

226. *Given: A simple curve, to replace it by another with spirals that shall* **pass through the same middle point,** *H*.

This is a special case of the last problem in which h equals zero. Select a spiral for D' a little greater than D and use the tabular value of p in eq. (300) to find an approximate value of R'. Take the tabular value of R' for the nearest minute and proceed as before to solve eq. (299) and eq. (301). This will result in a very small value of h, either *plus* or *minus*, which must be noted.

Example.—Given; D, 5°, Δ 48°, Spiral, n 7, c 26, p 1.59. Then, eq. (300), approx. $(R - R') = 18.39$ and R' 1127.89. Assume $R' = 1127.50$ for 5° 05′. Then $p = 1.554$, $h = 0.077$, $q = 90.139$, $d = 82.469$.

Otherwise, to make h precisely zero, we **have from the** equation above eq. (299)

$$R' = \frac{R \text{ vers } \tfrac{1}{2}\Delta - x}{\cos s - \cos \tfrac{1}{2}\Delta} \qquad (302)$$

and use the corresponding fractional value of D'. Find d by eq. (301).

227. *Given: A simple curve joining tangents, to* **compound it near each end so as to introduce a spiral.** Fig. 102.

In place of $\frac{1}{2}\Delta$ use some smaller angle θ, compounding at some point Q, and by substitution the last equation becomes

$$R' = \frac{R \text{ vers } \theta - x}{\cos s - \cos \theta} \tag{303}$$

Use the corresponding value of D' for the arc LQ. In eq. (301) substitute θ for $\frac{1}{2}\Delta$, and solve for d.

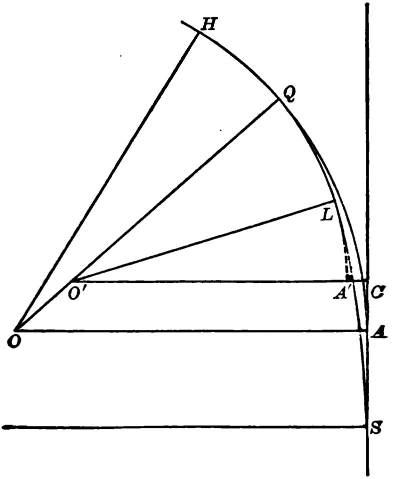

FIG. 102.

Otherwise, assume the nearest tabular value for R' and with this compute a new value for θ, thus fixing the position of the point Q. For this purpose, in eq. (303) write (vers θ − vers s) for (cos s − ccs θ) and solve for vers θ, whence,

$$\text{vers } \theta = \frac{x - R' \text{ vers } s}{R - R'} \tag{304}$$

The numerator is evidently the new value of p.

In eq. (301) make h equal zero and write θ for $\frac{1}{2}\Delta$, whence

$$d = y - R' \sin s - (R - R') \sin \theta$$

Example.—Given: D 3° and Spiral n 7, c 40, and θ = = 9° 10′.

By eq. (303)

$R' = 1729.31$ or $D' = 3° 18' 45''$; but assuming D' by eq. (304)

$$\text{vers}\,\theta = \frac{2.442}{190.96} = \text{vers}\ 9° 10' 22'',\ \text{and}\ AQ = 305.76$$

By eq. (305)

$$d = 279.802 - 139.865 - 30.442 = 109.495$$

Hence old line = SAQ = 415.255; new line = S 415.190.

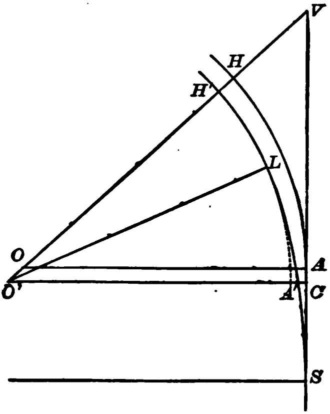

FIG. 103.

Note.—We may assume R' without using eq. (303) θ be not satisfactory, try again. If we assume R' fr for $(n + 1)$ of the spiral, we may use the tabular va p for the numerator in eq. (304).

228. *Given: A simple curve joining two tangents,* **to the curve inward so as to provide clearan spirals.** Fig. 103.

a. When the spirals are alike, the clearance is expres p in eq. (290). In eq. (299) make $R' = R$, whence

$$-h = \frac{x - R\,\text{vers}\,s}{\cos\frac{1}{2}\Delta} = \frac{p}{\cos\frac{1}{2}\Delta}$$

inus sign indicates movement toward the cente

Similarly, for the distance AS we obtain from eqs. (301) and (291) changing the sign of h,

$$d = q + h \sin \tfrac{1}{2}\Delta = q + p \tan \tfrac{1}{2}\Delta \tag{307}$$

The maximum displacement, h, occurs at the middle of the curve.

Both eqs. (306) and (307) may be easily derived from the figure as in § 225.

b. When different spirals are required: Fig. 104.

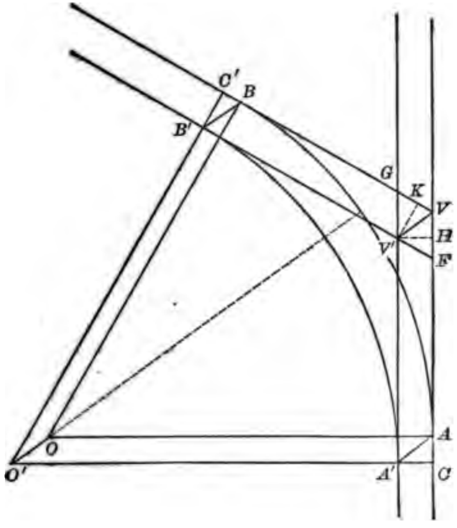

Fig. 104.

With the given value of R compute p, p', q, q', by eqs. (290) and (291), and let p be less than p'.

In the figure let V' be the intersection of parallel tangents, $V'H = p$ and $V'K = p'$. The diagonal $VV' = AA' = BB'$.

$$AC = VH = VF - HF \qquad BC' = VK = VG - KG$$

$$AC = \frac{p'}{\sin \Delta} - \frac{p}{\tan \Delta} \qquad BC' = \frac{p}{\sin \Delta} - \frac{p'}{\tan \Delta} \tag{308}$$

$$d = q + AC \qquad d' = q' + BC' \tag{309}$$

Note that if BC' should prove negative in (308) it the minus sign in (309). The maximum displaceme the curve equals VV' and is on the radius drawn pa to VV'.

$$\tan VV'H = \frac{AC}{p} \quad \text{and} \quad VV' = \frac{p}{\cos VV'H}$$

Example.—Given: $D = 5°$; $\Delta = 37°$; and spirals 8 × 30; $n'c' = 10 \times 36$.

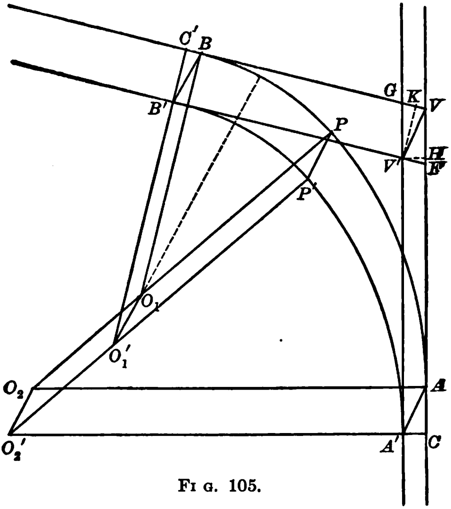

FIG. 105.

Then $s = 6°$; $s' = 9° 10'$; $p = 2.615$; $p' = 5$
$q = 119.903$; $q' = 176.427$; $AC = 5.641$; $BC' = 2$
$d = 125.544$; $d' = 173.496$; $VV'H = 65° 08'$; $VV' = 6$

The necessity for differing spirals seldom occurs wi simple curve. If the displacement should be objec able for any reason one of the preceding methods ma adopted instead.

Spirals with Compound Curves

229. *Given: A Compound Curve joining tangents,* ***move the entire curve inward so as to pro*** ***arance for spirals.*** Fig. 105.

As suitable spirals will necessarily differ, the general method of the last section will apply here. Designate the spiral values by the same subscripts as the arcs themselves, let R_1 be less than R_2 and $\Delta = \Delta_1 + \Delta_2$. With R_1 and s_1 find p_1 and q_1; also with R_2 and s_2 find p_2 and q_2, using eqs. (290) and (291).

Then, as in eq. (308):

$$AC = \frac{p_1}{\sin\Delta} - \frac{p_2}{\tan\Delta} \qquad BC' = \frac{p_2}{\sin\Delta} - \frac{p_1}{\tan\Delta} \qquad (311)$$

If BC' should prove negative give it the minus sign in the next formula.

$$d_1 = q_1 + BC' \qquad\qquad d_2 = q_2 + AC$$

$$\tan VV'H = \frac{AC}{p_2} \qquad\qquad VV' = \frac{p_2}{\cos VV'H}$$

The maximum displacement of the curve equals VV' and occurs on the radial line drawn parallel to VV'. If this radial line does not cut the curve between tangent points the curve displacement varies between the limits p_1 and p_2. The central angles of the resulting curve will be respectively

$$(\Delta_1 - s_1) \text{ and } (\Delta_2 - s_2)$$

Example.—Given:

D_1 8° 20′; Δ_1 25° 03′, n_1c_1 11 × 24, s_1 11°
D_2 3° 20′, Δ_2 38° 57′, n_2c_2 8 × 45, s_2 6°

Then we derive

p_1 4.974, p_2 3.923, q_1 131.680, q_2 179.883
AC 3.621, BC' 1.938, d_1 135.301, d_2 181.121
$VV'H$ 42° 42′, VV' 5.338 max. at 17° 39′ beyond P.

230. *Given: A Compound curve joining tangents,* **to replace it by another with spirals** *on the same ground and of the* **same length,** *as nearly as may be.* Fig. 106.

The point of compound, P, will be preserved, but moved outward by a small offset, h, and each arc may then be treated separately as though it were half of a simple curve. As each arc will be somewhat sharpened, select suitable spirals accordingly, assume a small value for h (see Table XL for values of h in various cases) and compute the new *radius* R_1' *and also* R_2', giving probably fractional degrees of curve. These may be adopted at once, or, if preferr new radius may be assumed for the nearest minut with it a new value for h computed, and with this pute the value of the other new radius.

With these final values proceed to compute d_1 and compare the lengths of the new and old lines.

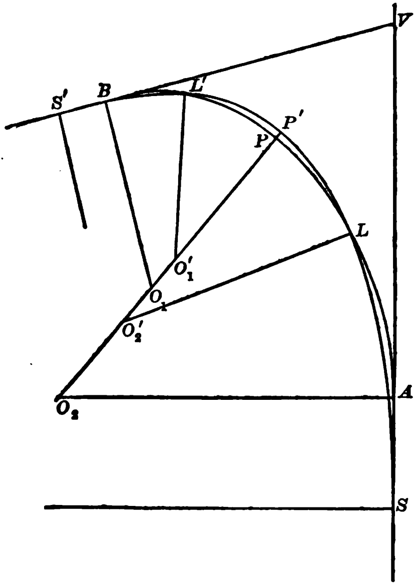

FIG. 106.

formulas for one arc are the same as in § 225 with change of notation; and are as follows:

$$R_1' = \frac{R \text{ vers } \Delta_1 - (x + h \cos \Delta_1)}{\cos s - \cos \Delta_1}$$

$$h \cos \Delta_1 = (R - R_1') \text{ vers } \Delta_1 - (x - R_1' \text{ vers } s)$$

$$d = y - R_1' \sin s - (R - R_1' + h) \sin \Delta_1$$

The same formulas apply to the other arc, only ch *e subscripts* where they occur.

Example.—Given:

$$D_1\ 8°;\ \Delta_1\ 29°;\ n\ 9,\ c\ 20$$

and

$$D_2\ 6°;\ \Delta_2\ 25°\ 06';\ n\ 9,\ c\ 26$$

Assume $h = 1$. Then $D_2' = 6°\ 16'\ 06''$; but for D_2' $6°\ 16'$, $h = .99054$, and for this value of h, $D_1' = 8°\ 17'\ 56''$ (say) $8°\ 18'$. Then $d_1 = 76.474$, $d_2 = 96.981$.

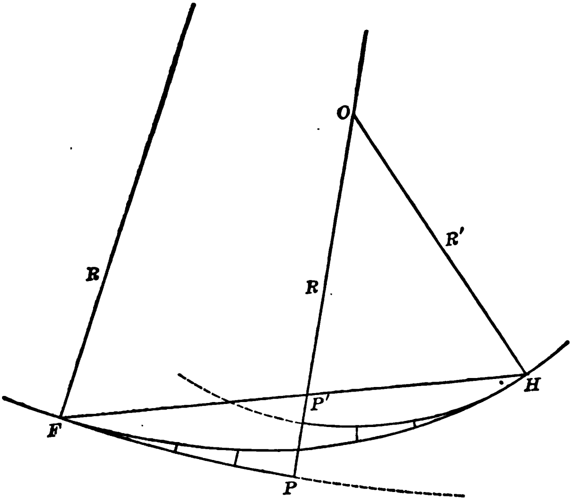

Fig. 107.

Length old line 439 + 515.3 = 954.3
Length new line 439 + 514.9 = 953.9

Given: A Compound curve, to apply spirals without disturbing the middle portion of the curve.

The methods discussed in §§ 226 and 227 apply here with merely a change in notation; letting P replace H, and Δ_1 or Δ_2 or θ replace $\frac{1}{2}\Delta$ as the case may require. In the case of three or more arcs in the curve only the terminal arcs are affected by the use of these methods.

231. *Given: A Compound curve, to introduce a spiral* **between arcs at the point of compound, *P*.** Fig. 107. The arcs must be separated by a radial offset at P to afford clearance for the spiral, the sharper arc being inside of the other. In general the spiral and offset bisect each other. In Table XXXVI under any one chord-length find two values of D_s corresponding, as nearly as possible to D_1 and D_2 and use the portion of the spiral included between them; lay off one half this length on each arc from P, for the new compounding points, F and H. From the point F the spiral FH may be located by deflections from the local tangent, using only the portion of spiral selected, and the deflections given *below* the zeros in Table XXXV for the point number represented by F.

Or the spiral may be located from H towards F by using the deflections given *above* the zeros in Table XXXV for the instrument at the point number represented by H. The sum of the angles taken from the two arcs equals the spiral angle for the portion of the spiral used. Should the distance FH prove to be a little longer or shorter than the spiral the several chord-lengths may be slightly altered.

Now the linear offsets from arc to spiral at the chord points are the same as from a tangent, regarding F or H as the point of Spiral S, and numbering the points from them as usual; the offset is equal to x given in the table. Thus, if the spiral is eight chords long, the fourth point from either end will be at P, consequently the offset PP' will equal $2x$ for $n = 4$ in the proper table.

But when the spiral has an odd number of chords the half length will bisect the middle chord, and the value of x is found by multiplying the chord by the coefficient here given opposite the half length of spiral.

Coefficients for x *at Half-chords*

n		*n*		*n*	
1.5	.00364	4.5	.05999	7.5	.24711
2.5	.01273	5.5	.10397	8.5	.35200
3.5	.03054	6.5	.16538	9.5	.48288

The spiral may be located by offsets, first laying out chord-lengths from P on one arc, and from P' on the other, setting off x at each point till F or H is reached, when

$x = 0$. If the spiral long chord FH be required, it may be computed by eq. (288) for the portion of the spiral actually used.

Example.—Given: a compound curve of D 4° and D' 12° to introduce a spiral at the P.C.C. In Table XXXVI under c 21 find at n 5, D_s 3° 58′ and at n 15, D_s 11° 55′; therefore the spiral will extend from point 5 to point 14, and the spiral angle s will be $(17° \; 30' - 2° \; 30') = 15°$. Divide this between the arcs in the ratio of their degree of curve, or $\frac{1}{4}$ and $\frac{3}{4}$ parts, 3° 45′ on the 4° curve, and 11° 15′ on the other. This takes 93.75 feet on each arc, total 187.50 feet; but the spiral measures $9 \times 21 = 189$ feet; the difference, 1.50 feet divided by 9 gives a correction of 0.17 for each chord-length; hence $c = 20.83$. The point n 5 is taken at F, and from Table XXXV "Inst. at 5" the deflection for point 6 is 30′. Make this and the succeeding deflections up to n 14 or H. At H deflect from chord HF to find tangent 8° 36′ 45″ (found "Inst. at 14" n 5) to complete the 15°.

The middle point of spiral is n 4.5 for which the coefficient is 0.06; hence the clearance $p = 2 \times 21 \times 0.06 = 2.52$ for separation of curves at P.

Field and Office Work

232. A spiral may be set out upon the ground in either direction by using the proper list of deflections, according to the point n at which the transit is placed, but to secure perfect agreement with the tangent it is better to proceed from the tangent point with each spiral, and afterward connect them by the intervening curve. The several points of the spiral, however, are not required except for track-laying, and in the earlier stages of the work it is sufficient to locate the extremities of the spiral by its long chord, SL. Any regular station of the survey which falls upon the spiral may be located by treating it as a *plus* between chord-points, making the deflection to it accordingly by ordinary interpolation. Strictly speaking, there is a second difference to be applied to the deflection so found (minus when running from S and plus when running from L), but as this amounts only to 12″.5 at the middle of a chord, it may usually be ignored. A transit point, if required on a spiral, *will be located at a regular* chord-point.

In a difficult country, where the line requires close adjustment to the contour, it is wise to ignore all spirals until a satisfactory location has been obtained. Spirals may then be introduced by any of the methods described. Only in a flat country, or where a very careful paper location has been projected, is it worth while to set out spirals at the first running.

In projecting a paper location it is desirable to have at hand a set of circular templets cut to the scale of the map and representing convenient degrees of curve. After finding by trial a curve that fits the topography when touching the tangents, locate the tangent point A by a perpendicular from the center, and withdraw the templet a little to give the necessary clearance p for the spiral. The distance moved along the line VO is

$$h = \frac{p}{\cos \frac{1}{2}\Delta} \tag{315}$$

The clearance may be too small to be shown accurately to scale, but the distance AS may be computed, eq. (307), and laid off to locate S from which the point L may be located by its coordinates, x and y. Or, the entire tangent distance VS may be computed and scaled. The spiral may be drawn with a suitable curved rule. It should sensibly bisect the offset p and be bisected by it very nearly.

When curves predominate these should be drawn first to suit the contours, but far enough apart to admit the necessary spirals and a bit of tangent. The tangent lines are then drawn to touch short arcs outside the curves at the distance p. Then from a radius drawn perpendicular to the tangent lay off q to locate S, and $R \sin s$ to locate M opposite L.

Table XXXIX supplies the quantities required for projecting curves and spirals in either field or office work for a selected list of simple curves. It furnishes also a means of computing correctly the spiral tangent T_s for any curve in the list by the use of the formula

$$T_s = T + q + p \tan \frac{1}{2}\Delta \tag{316}$$

in which T is the tangent distance for the simple curve. Much time may be saved by adopting in practice the curves listed

232a. The Ten-Chord Spiral. Instead of the multi-compound curve, discussed in this Chapter as the Railroad Spiral, we may use a curve of variable radius to effect the same result, namely, the easy transition on a railroad track from a tangent to a circular curve.

The essential condition in this case is that the variable radius of curvature at any point of the spiral shall be inversely as the length of arc to that point from the main tangent point. This secures a uniformly increasing degree of curvature from the tangent to the given circular curve and accords with the regular rise of the outer rail to the elevation required.

A spiral of this form has been adopted by the American Railway Engineering Association and is called "The Ten-Chord Spiral" from the fact that, in every instance, it is designed upon ten equal chords, which, taken together, constitute the length of the spiral. While theoretically the length of spiral signifies the length of its arc, yet in the case of flat arcs, or where the degree of curve does not exceed 8°, or the spiral angle does not exceed 15°, the measurement of the spiral by its chords gives practically correct results. Beyond these limits, however, certain small corrections become necessary.

232b. In the discussion of this spiral we have adopted the following:

NOTATION

r = radius of curvature at any point of the spiral;
R = radius of the circular curve, and limiting value of r;
d = degree of curvature at any one point of the spiral;
D = degree of curve of the circular curve, and limit of d;
l = length of spiral arc from S to any point on the spiral;
L = total length of spiral arc, and limiting value of l;
s = central angle of the spiral up to any point;
S = total spiral angle up to L, and limiting value of s;
i = deflection at S from the tangent to any spiral point;
I = total deflection to the point L, and limiting value of i.

232c. From the condition stated above we have at once

$$\frac{r}{R}=\frac{L}{l} \qquad (A)$$

and for flat arcs generally

$$\frac{d}{D}=\frac{l}{L} \qquad (B)$$

Since d is zero at the tangent point and increases unifo to its limit D at L, its average value is $\frac{1}{2}D$, and this n

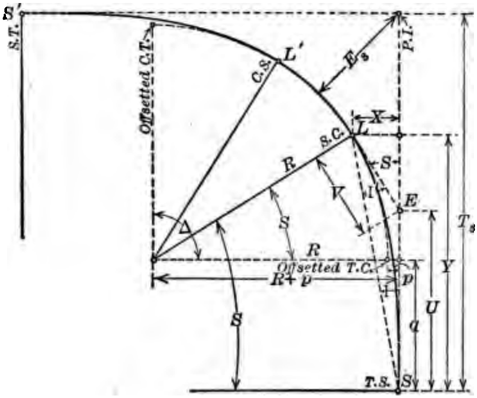

Fig. 107*a*.

plied by the length of the spiral in stations of 100 fee $\frac{L}{100}$, gives the central angle of the whole spiral, S (con eq. (18)).

$$S = \frac{LD}{200}$$

Similarly, for any other point of the spiral,

$$s = \frac{ld}{200}$$

Dividing s by S and substituting from eq. (B) we hav

$$\frac{s}{S} = \frac{l^2}{L^2}$$

or the spiral angles are to each other as the squares c lengths of spiral measured from the tangent point, S.

Substituting in eq. (C') the value of d from eq. (B) we

$$s = \frac{Dl^2}{200L}$$

in terms of D, L and l.

From the elementary triangle we have at any point of the spiral the differential equation,

$$dx = dl \cdot \sin s$$

and since for flat arcs

$$\sin s = s \text{ very nearly,}$$

$$dx = s \cdot dl = \frac{Dl^2 dl}{200L}$$

and by integration,

$$x = \frac{D \cdot l^3}{600L} \qquad (F)$$

in which D must be expressed in length of arc taken from Table XX, or else multiply the angle D by $\frac{\pi}{180°}$.

When $l = L$, x becomes X, and

$$X = \frac{D \cdot L^2}{600} \qquad (F')$$

For the deflection angle, i, $\sin i = \frac{x}{l}$ approx., and when i is small,

$$i = \frac{x}{l} = \frac{D \cdot l^2}{600L}$$

which, compared with eq. (E) gives

$$i = \frac{s}{3} \qquad (H)$$

when s does not exceed 15°.

Let x, y, be the variable coordinates of the spiral, taking the main tangent as the axis of Y with the origin at S. When s does not exceed 15°, x is given by eq. (F) and y by

$$y = l \cdot \cos i \qquad (I)$$

232d. All the above formulas give values for any point of the spiral, but the only points to be considered are at the intersections of the ten equal chords which measure its length. Let c be the length of one of these chords, and let a_1, a_2, a_3, etc., be the angles which these chords produced make with the tangent. To find their values:

If through any chord point, B of the spiral, Fig. 107b, and with the radius of curvature for that point we draw a circular arc having a common tangent at B, and from that point draw the short chord c, to the spiral at K, and another of the same length to the circular arc at G, then by the law of the spiral the angle GBK between these chords is equal to i_1 the deflection angle at S for the first chord, c.

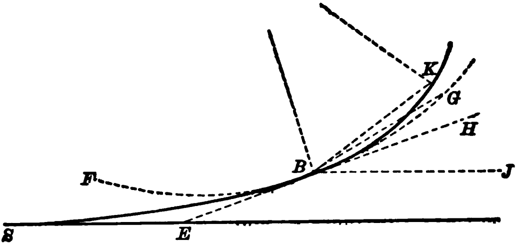

Fig. 107b.

Let the chord BK be the nth chord of the spiral, K the nth point and B the point $(n-1)$. Since the spiral angles are to each other as the squares of the distance from S, the spiral angle at B will be

$$s \text{ for the point } (n-1) = (n-1)^2 s_1$$

in which s_1 is the spiral angle for the first point n_1 and equal to $\frac{S}{100}$.

Let δ be the deflection angle from the common tangent at B to the chord BG. Then in general

$$\delta = \frac{cd}{200}$$

in which $c = \frac{L}{10}$ and from eq. (C') $\frac{d}{200} = \frac{s}{l}$.

Hence in general, $\delta = \frac{L \cdot s}{10l}$

But for the nth chord and the point $(n-1)$

$$l = \frac{(n-1)L}{10}$$

and

$$s = (n-1)^2 s_1$$

Hence, for the chord *BG*,

$$\delta = (n-1)s_1$$

Then the sum of the spiral angle, the deflection angle and the angle *GBK* is, for the *n*th chord,

$$a_n = \left[(n-1)^2 + (n-1) + \frac{1}{3}\right]s_1 \qquad (J)$$

or, in terms of a_1 which equals i_1,

$$a_n = (3n^2{}_1 - 3n + 1)a_1 \qquad (J')$$

If in the parenthesis we substitute in succession the numbers from 1 to 10 for *n* we get a series of coefficients of a_1 for all the chord points of the spiral, viz., 1, 7, 19, 37, 61, 91, 127, 169, 217, 271.

(Observe that these numbers are the first differences of the cubes of the serial numbers, 1 to 10; their differences are multiples of 6, and their second difference is 6, a constant.)

The values of *a* thus obtained serve only the purpose of deriving precise values of the coordinates, *x* and *y*, for the ten chord points when *s* is too large to admit of the assumption, $s = \sin s$, or $\sin i = \frac{x}{l}$, as is done in section 232c.

232e. Having the angle *a* which any chord, *c*, makes with the main tangent, multiply *c* by cos *a* and sin *a* respectively to obtain the projection of that chord upon the tangent and perpendicular. The successive addition of these projections gives the values of the coordinates, *x* and *y*, for the ten chord points of the spiral. This work has been done and tabulated once for all for various values of *S* and *L*. We may then obtain the precise value of the angle *i* for any point of a given spiral by

$$\tan i = \frac{x}{y} \quad \text{or} \quad \tan I = \frac{X}{Y} \qquad (K)$$

232f. Let *C* be the long chord *SL* of the spiral, and let *U* and *V* be the tangents *SE* and *EL* of the spiral, as in Fig. 107*a*; then as in section 220, we have at once,

$$C = \frac{Y}{\cos I} \quad \text{or} \quad C = \frac{X}{\sin I} \qquad (L)$$

$$U = Y - X\cot S; \quad V = \frac{X}{\sin S} \qquad (M)$$

in which X, Y, and S are taken from the table for the given spiral. Since the angle at E equals S, the deflection angle ELS is

$$I' = S - I \tag{N}$$

232g. If the circular curve of radius R were extended backward through the angle S, from L to A' the length of the extension would be half that of the spiral, or $\frac{1}{2}L$, and the point A' would be the tangent point of a tangent parallel to the main tangent.

Let q, p, be the coordinates of the point A' as in the figure. Then, as in Section 221,

$$q = Y - R \sin S \quad \text{and} \quad p = X - R \operatorname{vers} S \tag{P}$$

in which X and Y are the coordinates of the point L.

Values of q and p are given in Table XLVIII for certain values of D and L; also in Table XLIX the coefficients of D and L for finding q and p.

232h. Let T_s, E_s, be the tangent distance and external distance to the vertex for the combined spiral and circular curve, and let Δ be the total angle between tangents. Then from Fig. 107a we have

$$T_s = (R + p) \tan \tfrac{1}{2}\Delta + q \tag{Q}$$

$$E_s = (R + p) \operatorname{exsec} \tfrac{1}{2}\Delta + p \tag{R}$$

232i. On location surveys it is desirable to do all the fieldwork in a forward direction since the line and fieldnotes are continuous, and the second or closing spiral of a curve should form no exception to this rule. For forward work from L' eq. (N) gives the deflection I' and eq. (L) gives the long chord C, by which the closing tangent point S' may be reached; after verifying the position of this point and testing the closing angle I any station stakes required upon the spiral may be set. A station will usually occur as a "plus" between the spiral chord points.

It would be convenient to have a table of deflections for the spiral from the common tangent at the point L or L', but these deflections may be computed with little trouble since the deflections from points on the circular curve, LA' produced, spiral points are the same, point for point, as the deflections from the tangent given in Table XLV for the other end of the spiral. With a given value of the chord c take a series of points from L on the circular curve LA' and compute the deflections to them from the common tangent, deduct from these the tabular values of i_1, i_2, i_3, etc., found in Table XLV, and the differences will be the deflections required from the common tangent at L to the several spiral points, 9, 8, 7, etc. These results are correct up to 15° practically.

When giving centers for track laying it is desirable that the transit be set at the main tangent point in every case as this insures greater precision in alinement on the flat part of the spiral and perfect connection with the tangent.

Example.—Given: a spiral of 300 feet to connect a 6° curve with the following tangent, to find the deflections from the common tangent at L'.

By eq. (*C*) $S=9°$, $s_1=.09°=5.4'$, $i_1=1.8'$, $c=30$.

Point.	Circle.		Table XLV.		Deflec.
L'	0° 00.0′		0° 00.0′		0° 00.0′
9	0 54	–	0 1.8	=	52.2
8	1 48	–	7.2	=	1 40.8
7	2 42	–	16.2	=	2 25.8
6	3 36	–	28.8	=	3 07.2
5	4 30	–	45.0	=	3 45.0
4	5 24	–	1 04.8	=	4 19.2
3	6 18	–	1 28.2	=	4 49.8
2	7 12	–	1 55.2	=	5 16.8
1	8 06	–	2 25.8	=	5 40.2
S'	9 00	–	3 00.0	=	6 00.0

The same result will be obtained by multiplying i_1 by the coefficients in the last column of Table XLVI. For a check the second difference of the deflections is a constant, and equal to $2i_1$.

232j. Should it become necessary to use a transit point on the spiral one of the chord points will be selected for this purpose, preferably point 5. The deflections from the tangent at such a point will be computed on the principle given in the last section, using for the circle, however, the circle described by the radius of curvature of the spiral at the point selected. To these deflections apply the tabular values of i as before, *deducting* them for points between the transit and the main tangent, but *adding* them for points between the *transit and the circular* curve.

Example.—Given: a spiral of 300 feet located from either end as far as point 6, to find the remaining deflections from the local tangent at that point, in connection with a 6° curve.

At point 6 the degree of curvature is $\frac{6D}{10}$ or 3.6°, $c=30$ feet and $i_1=1.8'$ as before.

Point.	Circle.		Table XLV.		Deflection.
S	3° 14.4′	−	1° 4.8′	=	2° 9.6′
1	2 42.0	−	45.0	=	1 57.0
2	2 09.6	−	28.8	=	1 40.8
3	1 37.2	−	16.2	=	1 21.0
4	1 04.8	−	7.2	=	57.6
5	32.4	−	1.8	=	30.6
6	00.0		0.0		00.0
7	32.4	+	1.8	=	34.2
8	1 04.8	+	7.2	=	1 12.0
9	1 37.2	+	16.2	=	1 53.4
L	2 09.6	+	28.8	=	2 38.4

Note that the spiral points are numbered from the tangent toward the curve regardless of the direction in which the line is measured. When point 6 has been established the entire spiral may be located from this point, using these deflections. The same deflections may be obtained by multiplying i_1 by the coefficients in column 6 of Table XLVI. The second difference is constant.

232k. When it is desired to locate a spiral with the tape without a transit, first find X, the offset to the end of the spiral, and (since offsets vary as the cubes of their distances from the tangent point) divide the spiral into any convenient number of equal parts, divide X by the cube of this number for the first offset, and multiply this offset by the cube of succeeding numbers for the other offsets. Stretch a wire or cord to mark the line of the tangent, lay off from S along the spiral the length of chord adopted, setting each forward pin at the computed offset distance from the wire. The offset must be at right angles to the wire. This method is inferior to the transit method and should only be used in case of emergency. By dividing the spiral into eight equal parts the computation of offsets is somewhat simplified, the middle offset being $\frac{1}{8}X$, the first quarter offset one-eighth of this, and the first offset one-eighth of the latter; since 8 is the cube of 2.

Example.—Given: $D=8°$ and $L=280$ feet, to locate the spiral of ten points from the tangent. By Table XLVIII for point 10 find $X=18.20$; for point 1—point off three places, giving .0182; multiply this by 8 giving .1456 for point 2; and again by 8 for point 4, giving 1.1648; and again by 8 for point 8, giving 9.3184. Now multiply .0182 by 27 for point 3, giving .4914, and this by 27 for point 9, giving 13.2678, and also by 8, giving 3.9312 for point 6. Finally, for point 7 multiply .0182 by 343 giving 6.2426. For a check set these products in order in a column and take their differences; the third difference is constant, .1092. It is proper to compute with four decimal places, although only two places can be used on the ground.

232l. Although the length of spiral and degree of curve are arbitrary they bear a certain practical relation to each other, and while the curve as a whole must suit the topography, the spiral must not be too short to provide an easy transition, nor yet so long as to crowd the circular curve and increase unduly its degree. For limits in length of spiral consult Table XXXIII, having regard also to the probable speed of trains. Owing to its varying curvature a long spiral is less easily kept in true alinement than a circular curve. As a rule the two spirals of the same curve should be alike.

232m. To introduce a spiral between arcs of a compound curve. After relocating one of the arcs to provide the necessary offset at the point of juncture, P, assume the length of spiral L and lay off half of this from P on each arc. Let D be the difference in degree of curve of the two arcs, and by eq. (C) find S, and from Table XLV take out the deflections required. The transit being set on the flatter arc at five chords from P, find the chord points on the arc and make the spiral deflections from these to locate the corresponding points of the spiral; or, *add* these deflections to the tangential deflections for the arc points, and deflect the *sums* from the local tangent to the spiral.

If the transit is set on the sharper arc at five chords from P proceed in the same manner, but *subtract* the deflections and deflect the *differences* from the local tangent. This method is evidently the same as that described in § 232i. The required interval between arcs at the point P is *twice the offset at the fifth* point, and may be calculated. The entire spiral may be located by offsets from the arcs, the offsets being in the ratio of the cubes of the point numbers, and equal to the offsets from tangent to spiral described in § 232k

232n. To distinguish between the several transit points at which changes in alinement occur the Am. Ry. Eng. Assoc. has adopted the following notation. A transit point is designated by the initials of the two lines which unite at that point, the initials being given in the order in which the station numbers of the survey increase. Thus we have:

T. C. for change from Tangent to Circle.
T. S. for change from Tangent to Spiral.
S. C. for change from Spiral to Circle.
C. C. for change from Circle to Circle of differing degree.
C. S. for change from Circle to Spiral.
S. T. for change from Spiral to Tangent.
C. T. for change from Circle to Tangent.

CHAPTER X

LEVELING

233. The field operations with the Engineer's Level are of a more simple character than those performed with the transit, yet require equal skill and nicety of manipulation in order to produce trustworthy results. The transit is used to ascertain the relative horizontal position of points, the level to obtain their relative vertical position.

234. In order to express the elevation of points, they must be referred to some *level surface* of known (or assumed) elevation; and in order that the elevations may all be positive upward, this surface of reference should be selected below all the points to be considered. The level surface of reference is called **the datum.**

The elevation of the datum is always zero. The elevation of any point is its vertical height above the datum.

Near the coast the sea level is usually adopted as the datum; inland, the low water mark of a river or lake, etc.; but it is not necessary that the *datum* should coincide with a water surface. If any points whose elevations are to be ascertained are below the water surface, the latter may be assumed to have an elevation of 100 or 1000 feet instead of zero; that is, we remove the datum, in imagination, to 100 or 1000 feet below the level of the water surface.

235. In case of a survey commencing at a point quite remote from any important water surface, *any permanent point* may be selected as the original point of reference, and its elevation may be assumed at 100 or any other number of feet; that is, we fix the datum at the same number of feet below that point. The point of reference is called a *bench*, or **benchmark,** and is designated by the initials B.M. Other benches are established at intervals during a survey, and their elevations determined instrumentally. They are then convenient points of known elevation for future reference. We cannot *assume* the elevation of more than one bench on the same survey, else we should have more than one datum, and all the results would be thrown into confusion.

236. Having established the first bench and recorded its elevation, the next step is to set up the instrument firmly at a moderate distance from the bench, so that the telescope shall be somewhat higher than the bench, and in full view of a rod held vertically upon it. The instrument having been tested for its several adjustments, and found to be correct, the *line of sight* through the intersection of the cross-hairs is known to be horizontal when the bubble stands at the middle of its tube. Turning the line of sight upon the rod, the point of the rod covered by the horizontal cross-hair is known to be on a level with the cross-hair; and the latter is therefore *higher* than the bench by the distance intercepted on the rod from its lower end. Adding this distance to the elevation of the bench, we obtain the elevation of the cross-hair, known technically as the "**Height of Instrument,**" and designated by the initials H.I.

237. The distance intercepted on a rod from its lower end by the line of sight, when the rod is held vertically on any given point, is called the **reading** *of the rod* at that point.

238. Having obtained the height of instrument, the elevation of any point somewhat lower than the cross-hair is easily ascertained by taking a reading of the rod upon it. The reading subtracted from the height of instrument gives the elevation of the point above the datum. The elevation of any number of other points may be similarly obtained. But the elevation of points on the ground higher than the cross-hair, or farther below it than the length of the rod, cannot be determined, because in either case the line of sight will not cut the rod, and hence there can be no reading. In order to observe such points, the instrument must be removed to a new position, higher or lower than before, as the case may require.

239. Before the instrument is removed to a new position, a *temporary bench*, called a **Turning Point** (*and designated* by T.P. or "*Peg*") must be established, and its *elevation* ascertained as for any other point, but with more care. A turning point must be a *firm* and *definite* point whose position cannot readily be altered in the least, nor lost sight of. A small stake firmly driven, or a point of rock projecting upward, is frequently used. The reading having been taken on the turning point, the instrument is carried forward to a new position, leveled up properly, and the new Height of Instrument obtained by a new reading on the same turning point. Since the cross-hair is higher than the point (otherwise there could be no reading) the reading, added to the elevation of the point, gives the Height of Instrument.

240. In general, the intersection of the cross-hairs being higher than any point on which a reading is taken:

To find the Height of Instrument, **add** *the reading on a point to the elevation of the point;* and

To find the Elevation of a point, **subtract** *the reading on it from the Height of Instrument.*

A reading taken for the purpose of finding the Height of Instrument is called a **Backsight** (B.S.). A reading taken for the purpose of finding the elevation of a turning point (or of a bench used as such) is called a **Foresight** (F.S.). Hence Backsights are always *plus*, and Foresights always *minus*.

It is to be noted that the terms Backsight and Foresight do not refer to the directions in which the sights are taken.

241. The form of field-book used for the survey of a railroad, or other continuous line, is shown below. The *first* column contains the numbers of the stations on the line and of plus distances to other points on the line where readings are taken—also the initials of benches and turning points, in order, as they occur. The *second* column contains the backsights, taken on points of known elevation only. The *third* column contains the height of instrument, recorded on the same line as the elevation of the turning point (or bench) from which it is calculated. The *fourth* column contains the foresights, taken on new turning points, and benches used as such, only. The *fifth* column contains the readings taken on all other points noted in the first column. The *sixth* column contains the elevations of all points observed. The right-hand page is reserved for remarks, descriptive of the benches and their location—of objects crossed by the line, as roads, streams, swamps, ditches, etc., the depths of streams, etc.

LEVEL BOOK.

Sta.	B.S.	H.I.	F.S.	Rod.	Elev.	Remarks.
B.M.	4.683	204.683			200.000	White oak, 115 R.
0				2.1	202.6	
1				3.4	201.3	
+50				5.2	199.5	
T.P.	1.791	197.260	9.214		195.469	
2				3.7	193.6	
+25				7.0	190.3	Brook 5 wide; 1 deep
+50				3.1	194.2	
3				0.5	196.8	
T.P.	11.750	208.574	0.436		196.824	
T.P.	11.938	219.528	0.979		207.595	
+90				3.5	216.0	
4				2.6	216.9	
B.M.				2.075	217.453	Maple, 78L.
5				1.7	217.8	
6				0.9	218.6	
T.P.	9.005	227.801	0.732		218.796	
7				6.2	221.6	
	39.162		11.361			

When a bench is not used as a turning point, the reading on it is recorded in the fifth column.

The numbers in the second, fourth, and fifth columns come directly from the rod, those in the third are obtained by addition, those in the sixth by subtraction, according to the rule given above. The additions and subtractions made on each page should be *proved* before proceeding to the calculations of the next. When correct, the difference of the sums of the backsights and foresights on the page equals the difference of the first and last elevations on the page. Thus, in the form given

$$(39.162 - 11.361) = (227.801 - 200.000) = 27.801$$

In this proof we ignore all elevations except those of turning points, and benches used as such, and the height of instrument.

At the end of the survey, as well as at the end of each day's work, a bench is established from which the survey may be resumed at any future time. See §§ 28, 29 and 80.

242. The object of making such a survey with level and rod is to furnish a **profile** or vertical section of the entire line, showing in detail the rise and fall of the surface over which it passes. The profile is plotted on profile-paper published for the purpose, the horizontal scale being usually 400 feet to an inch, and the vertical scale 30 feet to an inch. This distortion of scale magnifies the vertical measures so that slight changes in the elevation of the surface may be seen distinctly.

243. When only the difference of level of two extreme points is required, the survey is more simple. No readings are taken except on turning points, the backsights and foresights being recorded in separate columns. No calculation is required until the survey is finished, when—the first reading having been taken on one of the given points, and the last on the other—the difference of the sums of the backsights and foresights is the difference in elevation of the two points, according to the method of proof mentioned in § 241. Thus the difference in level of any two benches established on a previous survey may be tested, and, if found correct, all the intermediate elevations on the line may be assumed to be correct also. The discrepancy should not exceed one tenth of a foot in any case, and is usually much less.

244. Any lack of adjustment in the instrument gives the line of sight a slight angle of elevation or depression causing a slight error in every reading, proportional to the distance of the rod from the instrument. But the errors being equal for equal distances, and the backsights and foresights having opposite signs in our calculations, the errors cancel when the distances are equal. Hence, to avoid errors in elevation, each new turning point should be as nearly as possible at the same distance from the instrument as the point on which the last backsight was taken. For precise reading, the rod should not be more than 400 feet from the instrument.

245. Another cause of error in readings is want of verticality in the rod. This may be avoided by the use of a disk-level, or in the absence of wind, by balancing the rod. The rod may be plumbed one way by the vertical cross-hair of the level, and to ensure a vertical reading in the plane of the line of sight, the rod may be gently waved each side of the vertical toward and from the instrument, the shortest reading being the correct one; or in case of a target rod the target should rise *to*, but not *above* the horizontal cross-hair, as the rod is waved.

246. When very long sights are required to be taken with the level, another source of error must be considered, namely, the curvature of the earth.

A level line is parallel to a great circle of the earth, and is therefore an arc of a circle, or may be so considered.

A horizontal line is a straight line parallel to the plane of the horizon. Therefore the line of sight, being a horizontal line, is tangent to the circle of a level line passing through the instrument.

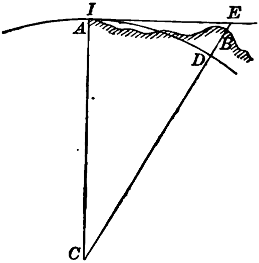

FIG. 108.

To find the correction in elevation due to **curvature of the earth** *for any distant station.* Fig. 108.

Let A be the station of the instrument I, and B the distant station observed.

Let $R_0 = CI$ = the radius of curvature of the earth, or of the parallel arc ID. Let $L_0 = ID$ = the level distance between A and B. Then IE, perpendicular to CI, is the line of sight, BE is the reading of the rod, and $DE = E_0$ = the correction due to curvature.

By Table XLI, 24, $IE^2 = DE(DE + 2R_0)$; but since DE is very small compared with $2R_0$, it may be omitted from the parenthesis, and since $IE = ID = L_0$ very nearly, because the angle ACB is very small, we have $L_0^2 = 2R_0E_0$.

$$\therefore \qquad E_0 = \frac{L_0^2}{2R_0} \qquad (317)$$

E_0 *is to be added* to the apparent elevation of station B.

247. Refraction. In observing distant stations the line of sight passing through the atmosphere is refracted from the straight line IE, Fig. 108, and takes the form of a curve, which, for practical purposes, may be considered as the arc of a circle, concave downwards. Its radius, depending on the conditions of the atmosphere, varies from 5½ to 7½ times the radius of curvature of the earth. $7R_0$ is considered a good average value.

Refraction causes the observed object to appear too high, while the curvature of the earth causes it to appear too low the effects being contrary, the correction for curvature is reduced by the correction for refraction. If we let H_0 = the total correction for both curvature and refraction, to be *added* to the apparent elevation of the observed object, then

$$H_0 = \frac{6}{7}E_0 = \frac{3L_0^2}{7R_0} \tag{318}$$

Table XVII is calculated by this formula, assuming a mean value of R_0 = 20,913,650 feet.

248. The form of the earth is approximately an ellipsoid of revolution. Its meridian section at the mean level of the sea is an ellipse, the semi-axes of which are, according to Clarke,

at the equator A = 6,378,206 meters [6.8046985]
at the poles B = 6,356,584 meters [6.8032238]

According to the same authority

1 meter = 3.280869 feet [0.5159889]

Therefore the semi-axes expressed in feet are

A = 20,926,058 feet [7.3206874]
B = 20,855,119 feet [7.3192127]

Then the radius of curvature of the meridian

$$\text{at the equator, } \frac{B^2}{A} = R_0 = 20{,}784{,}422 \text{ feet } [7.3177379]$$

$$\text{at the poles, } \frac{A^2}{B} = R_0 = 20{,}997{,}240 \text{ feet } [7.3221622]$$

In latitude 40° the radius of curvature of the meridian is 20,871,900, and of a section at right angles to the meridian, 20,955,400; the mean value, or R_0 = 20,913,650 [7.320430], being adopted for general use. The error in the correction H_0 *eq. (318) due to* this assumption will usually be much less than that due to the assumed value of the radius of refraction.

249. Leveling by Transit. When a transit has a level-tube attached to the telescope, it may be used for finding the difference in elevation of points. If the instrument be in perfect adjustment, the line of sight will be horizontal when the bubble stands at the middle point of the tube, and the reading of the vertical circle will be zero. Should there be a small reading when the line of sight is horizontal it is called the *index error*. When the line of sight is not horizontal, the angle which it makes with the plane of the horizon is called an angle of elevation, or of depression, according as the object upon which the line of sight is directed is above or below the telescope. This angle is measured on the vertical circle, being the *difference* of the reading and the index error, when both are on the same side of the zero mark, and their *sum*, when they are on opposite sides. When the distance to an observed object is known, and its angle of elevation or depression is measured, we may calculate its vertical height above or below the telescope.

Let $\pm\alpha$ = angle of $\left\{\begin{array}{l}\text{elevation;}\\ \text{depression;}\end{array}\right.$

L = the horizontal distance;

L' = the distance parallel to line of sight;

h = difference in elevation of object and instrument.

Then for short distances,

$$h = L \tan\alpha = L' \sin\alpha \tag{319}$$

For long distances the curvature of the earth and refraction must be considered. Fig. 109.

Let I be the place of the instrument, and F the object observed.

Let L_0 = the distance, measured on the chord of the level arc ID, passing through the instrument; and let ψ = the number of seconds in the arc ID; hence, since for ordinary distances the chord and arc are sensibly equal

$$\psi = \frac{L_0}{R_0} 206264''.8 \qquad [5.314425]$$

or giving to R_0 its mean value, § 248,

$$\psi = L_0 \times .0098627 \qquad [7.993995]$$

a fraction less than 1″ per 100 feet.

Let IF be the arc of the refracted ray, and assuming that its radius is $7R_0$, the arc will contain one seventh the number of seconds of the arc IF.

IF', tangent to IF, is the direction of the telescope; IF is the chord of the arc IF, and IE is the horizontal.

Let $\alpha = EIF'$ = observed angle of elevation. Then EIF = true angle of elevation $= EIF' - F'IF = \alpha - \frac{1}{2}\cdot\frac{1}{7}\psi = \alpha - 0.071\psi$.

The angle $EID = \frac{1}{2}\psi \quad \therefore DIF = \frac{1}{2}\psi + \alpha - 0.071\psi$; and $IDF = 90° + \frac{1}{2}\psi. \quad \therefore IFD = 90° - (\psi + \alpha - 0.071\psi)$.

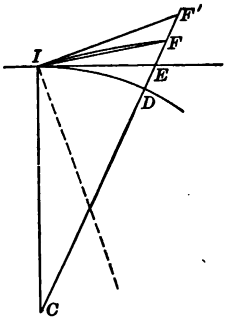

FIG. 109.

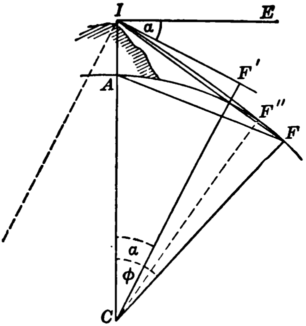

FIG. 110.

We now solve the triangle IFD for the side $DF = h$, and find

$$h = L_0 \frac{\sin\left(\frac{1}{2}\psi + \alpha - .071\psi\right)}{\cos\left(\psi + \alpha - .071\psi\right)} \tag{320}$$

For an observed angle of depression make α negative in the formula.

The coefficient 0.071 is called the coefficient of refraction, this being a fair average value, while its extreme range is from 0.067 to 0.100 under varying conditions of the atmosphere, and values of the angle α.

When the difference in elevation of two or more distant objects is required, we obtain the elevation of each separately, and subtract one elevation from another. The elevation of the observed object is given by (H.I.) ± h.

250. *To find the* Height of Instrument of a transit *by an observation of the horizon.* Fig. 110.

Let I be the place of the instrument, and let α = observed angle of depression of the horizon.

Let F be the point where the refracted ray meets the level surface, and draw the chords IF and AF.

Let ψ = the angle ACF, let $h = AI$, and let k = the coefficient of refraction.

In the triangle IAF,

$IAF = 90° + \frac{1}{2}\psi$, $AFI = \frac{1}{2}\psi - k\psi$, $AIF = 90° - (\psi - k\psi)$

Hence $FIE = \psi - k\psi$. But $FIE = \alpha + k\psi$

$$\therefore \qquad \psi = \frac{\alpha}{1 - 2k} \qquad (321)$$

Let F'' be the tangent point of a right line drawn through I; then $AI = CF''$ ex sec ACF'', but $CF'' = R_0$, and, since ψ is always very small, $ACF'' = \frac{1}{2}(\psi + \alpha)$ very nearly $= \frac{1 - k}{1 - 2k}\alpha$

$$\therefore \qquad h = R_0 \text{ ex sec} \frac{1 - k}{1 - 2k}\alpha \qquad (322)$$

Giving to R_0 its mean value, § 248, and assuming $k = \frac{1}{14}$

$$\log h = 7.320430 + \log \text{ex sec. } 1.0801\, \alpha \qquad (323)$$

Otherwise; we may solve the triangle AIF since

$$AF = 2R_0 \sin \tfrac{1}{2}\psi = 2R_0 \sin \frac{\alpha}{2(1 - 2k)}$$

and

$$h = AF \frac{\sin (\frac{1}{2}\psi - k\psi)}{\cos (\psi - k\psi)}$$

$$\therefore \qquad h = 2R_0 \sin \frac{\alpha}{2(1 - 2k)} \cdot \frac{\sin \frac{1}{2}\alpha}{\cos \frac{1 - k}{1 - 2k}\alpha} \qquad (324)$$

When $k = \frac{1}{14}$

$$h = 2R_0 \sin \tfrac{7}{12}\alpha \cdot \frac{\sin \frac{1}{2}\alpha}{\cos \frac{13}{12}\alpha} \qquad (325)$$

Example.—The observed dip of the sea horizon is 24′ = α. What is the height of the instrument above the sea?

By eq. (323) $1.0801 \times \alpha \times 60 = 1555''.34$ 3.191825
2

6.383650
Table XXVI $(q - 2l)$ 9.070130
R_0 7.320430

$h = 594.58$ 2.774210

Methods of determining heights by distant observations cannot be relied on for more than approximate results, since they necessarily involve the uncertain element of refraction, and usually a lack of precision in the vertical angle, the arc reading only to minutes in ordinary instruments. These methods, however, are useful where no great accuracy is required, as for a temporary purpose until levels can be taken in the regular way, or for interpolating between points of established elevation.

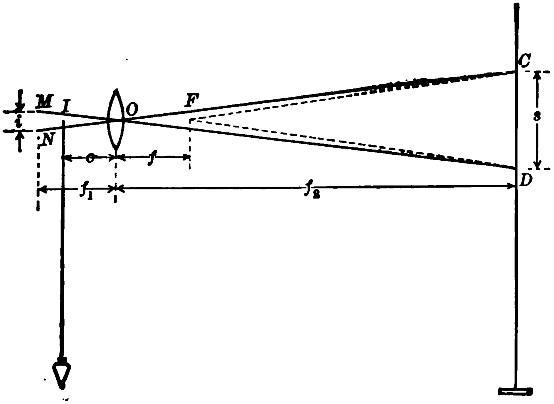

FIG. 111.

251. Stadia Measurements. It is sometimes convenient to determine distances by instrumental observation. For this purpose two additional cross-hairs may be placed in the telescope parallel to each other and equidistant from the central cross-hair. These are called stadia hairs, and distances determined by them are called stadia measurements. The stadia hairs are adjusted so as to intercept a certain space on a rod held at a certain distance from the instrument and perpendicular to the line of sight. For any other place of the rod, the distances and intercepted spaces are nearly proportional. The exact relation is given below. Fig. 111.

Let M and N be the position of the stadia hairs, the distance between them being denoted by i; $s = CD =$ the *space or "intercept"* on the rod between the two hairs.

The triangles *MON* and *COD* are similar, and

$$f_2 : f_1 :: CD : MN$$

or

$$\frac{f_2}{f_1} = \frac{s}{i} \qquad (326)$$

Let f be the focal length of the objective lens; then from Optics, we have

$$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f}$$

which, combined with eq. (326) will give

$$f_2 = \frac{f}{i}s + f$$

Now $f_2 + c =$ the distance from the center of the instrument to the rod $= D$.

$$\therefore \quad D = (f_2 + c) = \frac{f}{i}s + (f + c) = ks + (f + c) \qquad (327)$$

If the rod is held at any other distance from the instrument, its position may be found by multiplying the space intercept on the rod by $\frac{f}{i}$ and adding $(f + c)$ to the product.

The values of f, c and $\frac{f}{i}$ may be furnished by the maker, but if not, they may be determined by the observer. The value of f is found by focusing the object glass on a point at an infinite distance, and measuring the distance from the plane of the cross-wires to the center of the object glass. The value of c is the distance from the center of the instrument to the center of the object glass when focused at a point about 200 feet away. To find $\frac{f}{i}$ lay off a distance $(f + c)$ from the center of the instrument, which locates a point below F in Fig. 111. Take intercepts at different distances from this point. Divide each distance by its intercept. The average of the different quotients will be the value of $\frac{f}{i}$ or k.

It is to be noted that the work should be done on a nearly level stretch of ground and that the telescope bubble should *be practically* in the center at all sights; that is, in order to *affect a coincidence* the upper or lower cross-hair should not be moved over more than the smallest graduation of the rod.

252. Inclined Sights. Fig. 112. If the rod were held perpendicular to the line of sight, a portion of it would be in the position $C'D'$. It is not practicable to do this, as there is no easy method of securing the proper angle of inclination; therefore, the rod is held vertical, and a correction is made for this position. The inclined distance, IG, is then obtained, and finally the horizontal distance IE.

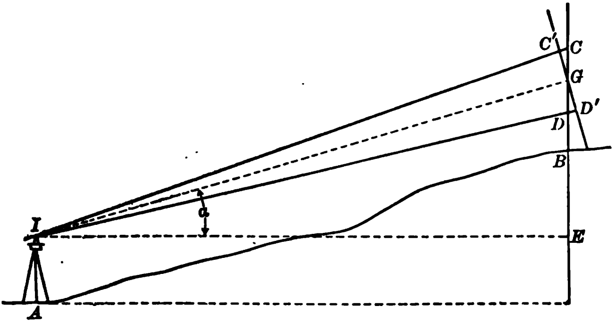

FIG. 112.

Let $C'D' = s'$ and $CD = s$.

Then
$$C'D' = CD \cos a = s \cos a$$
Now
$$IG = ks' + (f + c) = ks \cos a + (f + c)$$
But
$$IE = H = IG \cos a$$
and substituting the value of IG, we get
$$H = ks \cos^2 a + (f + c) \cos a \qquad (328)$$
Similarly,
$$GE = V = IG \sin a$$
or
$$V = ks \sin a \cos a + (f + c) \sin a$$
$$= \tfrac{1}{2}ks \sin 2a + (f + c) \sin a \qquad (329)$$

Reductions.—Table XVIII is used in finding horizontal distances and differences in elevation.

Under "Correction to Horizontal Distances" are give 100 minus $ks \cos^2 a$ for different values of a, when $k = 10$ and $s = 1$. Proper multiplication is made for other values o these quantities.

The quantities in the table under "Diff. Elev." are value of $\frac{1}{2}ks \sin 2a$ where $k = 100$, $s = 1$ and a = the particula vertical angle. With any other values of k and s the product is found by use of the slide rule. The quantities at th foot of the column are values of $(f + c) \sin a$ for three value of $(f + c)$. The products of the other values of $(f + c)$ ar found by interpolating.

Example.—Angle 2° 46′; rod reading 2.64; $f + c = 1.1$; and $k = 100$.

Difference in elevation = 4.82 × 2.64 + 0.04 = 12.76.

Correction for horizontal distance for 100 feet = 0.23 and for a rod reading of 2.64, it is 2.64 × 0.23 or 0.6. Correction for $(f + c) \cos a$ is 1.1. Therefore the horizontal distance = 264 − 0.6 + 1.1 = 264.5.

CHAPTER XI

CROSS-SECTIONS

253. The established grade upon the final profile of a located line is the basis to which all the work of construction must conform. The roadbed must be brought to grade and made of a prescribed width, while its slopes, either in cut or fill, must be provided for. Before the contractor can proceed a portion of the work must be staked out for him and a record of the measurements made by which the amount of material to be moved may be computed. This staking out of earthwork is called cross-sectioning. All cross-sections are taken in vertical planes at right angles to the center line.

The frequency with which cross-sections should be taken depends entirely upon the form of the surface; where this is regular, a section at each station is sufficient. A cross-section should be taken, not only at every point on the center line where there is an angle in the profile, but also wherever an angle would be found in the profile of a line joining a series of slope stakes on either side, even though the profile of the center line may be quite regular at the corresponding point—the object being, not only to indicate the proper outlines of the earthwork, but to furnish the data necessary to calculate correctly the quantities of material removed. Rockwork will generally require more frequent sections than earthwork.

The base of a cross-section is identical with the width of the roadbed. It is made wider in cuts than in fills to allow for the side ditches. Six feet should be allowed in earth, and 4 feet in rock cuts. **The ratio of the side slopes** depends upon the material. The usual slope ratio for earth is 1½ horizontal to 1 vertical for both excavation and embankment. Damp clay and solid gravel beds will stand for a time in cuts at 1 to 1, or an angle of 45°, but this cannot be permanently depended on. On the other hand, fine sand and very wet clay may require slopes of 1¾ to 1 or 2 to 1. Exceptional cases require slopes of 3 or 4 to 1. In rockwork the slopes are usually made at ¼ to 1 for solid, ½ to 1 for loose, and 1 to 1 for very loose rock, liable to disintegrate. Rock embankments stand at 1 to 1.

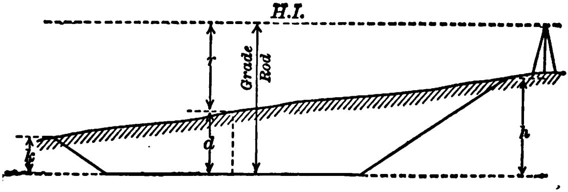

Fig. 113.

254. Since all points of importance on the natural surface have to be referred to grade to ascertain the depth of cut or fill necessary at each point, it is convenient to employ what is known as the **Grade rod**. This is simply the difference between any given height of instrument (H.I.) and the elevation of grade at the given point, or what a rod would read from the instrument if its foot were at grade. When the grade is above the H.I. the rod is supposed to be inverted. The cut or fill at the given point is determined by comparing the rod reading at that point with the grade rod. Any change in the H.I. requires the finding of a new grade rod. With the same H.I., the grade rod changes with the grade from station to station. If r_0 be the grade rod and r any rod eading, then (Fig. 113)

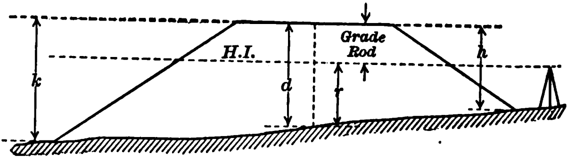

Fig. 114.

$$\left.\begin{array}{ll}\text{Depth of cut} & = r_g - r\\ \text{Depth of fill} & = r - r_g\\ \text{but (Fig. 114)} & \\ \text{Depth of fill} & = r_g + r \text{ when grade is above H.I.}\end{array}\right\} \quad (330)$$

255. Cross-sections are divided into four classes, depending upon the slope and shape of the natural surface, *viz.*, level, three-level, irregular and side-hill. The following notation applies in any case (Figs. 115, 116, 117):

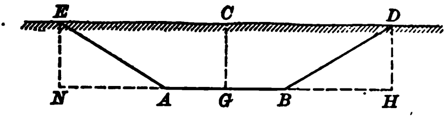

Fig. 115.

Let $b = AB$, the base of the section or roadbed;

$s = \dfrac{BH}{DH}$ = the slope ratio;

$d = CG$ = the cut (or fill) at the center stake;

$h = DH$ = the cut (or fill) on the right of the section;

and $k = EN$ that on the left;

$x = CD$ or CE the "distance out" from center to side stake.

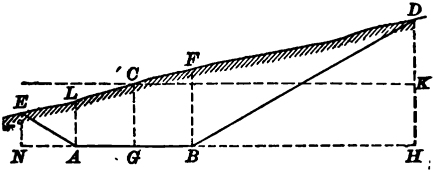

Fig. 116.

First read the rod at the station and find d from the grade rod, § 254; record d in the notes as cut or fill, and mark the same on the back of the stake; then proceed to locate other required points of the section, recording their distance from the center line and height or depth above or below grade. *Drive stakes* at the extreme points right or left called slope stakes, and mark on each the proper cut or fill, facing the stake toward the center. Cuts are marked + or C, fills − or F.

Level section. Fig. 115. Since $h = k = d$

$$x = \tfrac{1}{2}b + sd \qquad (331)$$

Three-level section. Fig. 116.

$$\left.\begin{aligned} x &= \tfrac{1}{2}b + sh \\ x &= \tfrac{1}{2}b + sk \end{aligned}\right\} \qquad (332)$$

Having found the center depth d, estimate from this and the apparent slope of the ground the probable depth h at the side, and from this compute a value of x (approx.) by eq. (332), measure out this distance to a point and take a rod reading which in eq. (330) gives a new h, and this in eq. (332) gives a new x; measure this cut as before, and repeat until the computed x agrees with the last measurement, proving that the correct point for the slope stake has been found. This method applies to all cases of either cut or fill by observing to make the proper additions or subtractions, such as the case in hand requires. A little practice enables one to combine somewhat these several approximations and so to arrive more quickly at the required point.

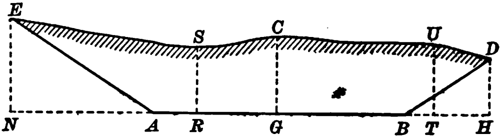

FIG. 117.

Irregular Section. Fig. 117. Proceed as in the last case, but before seeking the extreme points find the distance from the center line to any point where the surface of the section changes, and record the depth to grade at such point. Finally, by estimate and trial, locate the slope stakes as in the former case.

In all three cases the method is the same whether the section is for cut or fill.

Side-hill Section. A section is so named when its base or *roadbed* is partly in cut and partly in fill. Set the rod *the grade-rod* reading and move the rod along the section until the grade point is found; note its distance from the center and set a stake there, marked 0.0, facing it down hill. Find and note other points as in the other cases, but observe that $\frac{1}{2}b$ has different values in cut and fill, also that s may have two values, one for cut and one for fill. When the cut on the lower side is less than 1 foot it is well to go beyond that stake and set a grade stake, noting the distance out; thus changing a thorough cut into a side-hill section.

256. When two materials are found in the same section, as rock overlaid with earth, each material requires its own slope, and a **compound section** is the result. *To stake out work of this description,* the depth of the earth to the rock must be known, and may be nearly ascertained by reference to an adjacent section already excavated. Fig 118.

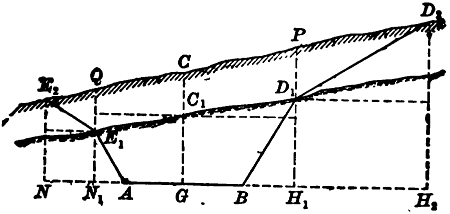

FIG. 118.

Let a_1 be the depth of earth at C;
a_2 be the depth of earth at P or Q;
s_1 be the ratio of rock slope;
s_2 be the ratio of earth slope.

Then $$x = \tfrac{1}{2}b + s_1(d - a_1 \pm y_1) + s_2(a_2 \pm y_2) \qquad (333)$$

in which y_1 = difference of rod readings on the *rock* at C_1 and D_1, or C_1 and E_1; and y_2 = difference of rod readings on the *surface* at P and D_2, or at Q and E_2. The upper sign applies to the upper side, the lower sign to the lower.

It is better, however, to make an indefinite cross-profile at first, driving two reference stakes quite beyond the section limits; and when the contractor has removed the earth from between D_1 and E_1, indicate to him those exact points by marks on the rock, and also set the slope stakes at D_2 and E_2.

257. Terminal Sections. A grade stake is set on the center line where it passes from cut to fill, also on each of the base lines if the contour crosses the line obliquely, and a section is required at each to define the terminal pyramids. The grade stakes are located by trial on the ground, using the grade-rod reading. Fig. 119 illustrates this case, showing the roadbed in plan and the place of cross-sections by dotted lines. The notes of these sections appear in the form of fieldbook.

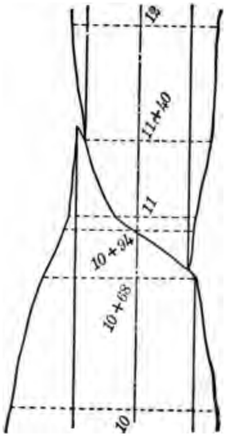

FIG. 119.

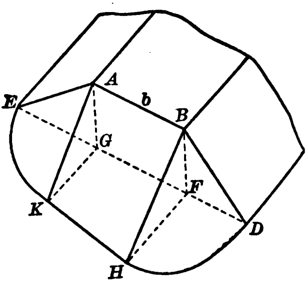

FIG. 120.

When an embankment ends *at a trestle* the material takes its natural slope at the ends as well as at the sides. Fig. 120. *ABDE* is the last cross-section, but end stakes are to be set at *H* and *K* to define the end sections taken parallel to the center line. The amount of material in the terminal wedge and quarter-cones may then be computed and added to the rest of the earthwork.

258. Other Methods. Where the transverse slope of e *ground is steep* it may be impossible to locate the slope es *at one setting* of the level; sometimes several settings may be required, involving finding a new H.I. and a new grade rod each time. In such cases the section may well be taken with a *level board and rod,* beginning with d at the center line and stepping up or down from the center line as far as the section may require. Here, as before, the true place of the slope stake is where the distance from the center and the depth to grade satisfy the formula, eq. (332).

When the transverse slope is quite regular within the limits of the section its slope ratio, s', may be ascertained and used to find approximately the distance to the required slope stake. This done in advance will save several trial computations on the way in case of a deep section, by whatever method the section may be staked out. For this purpose, find the depth, BF, at the edge of the base; then in Fig. 116,

$$BH = sh = s'(h - BF)$$

from which

$$h = \frac{s'}{s' - s} BF$$

and this in eq. (332) gives

$$x = \tfrac{1}{2}b + \frac{ss'}{s' - s} BF \tag{334}$$

which applies to the *deep side* in either cuts or fills.

Similarly, for the *shallow side,*

$$x = \tfrac{1}{2}b + \frac{ss'}{s' + s} AL \tag{335}$$

259. Where a number of consecutive sections have been taken by level board it is well to run a special line of levels along the slope stakes, verifying or correcting h and consequently x in each section, and resetting a slope stake when necessary, at the same time correcting the section notes. All benches have been verified by the test level survey, but occasionally a surface elevation may be found in error on the center line, especially at a *plus* between stations where a cross-section is desired. Level board work should start with a correct value of d.

260. Form of Field-book. A complete record of all cross-section work is kept in the cross-section book. On the left-hand page is recorded, in the *first column,* the numbers of the stations and other points where sections *are taken; in the second,* the elevations of those poi copied in part from the location level-book, but verified or corrected at the time the section is taken; *in the third,* the elevation of the grade for the same points; *in the fourth,* the width of base *b*; *in the fifth,* the slope ratios, *s*; and *in the sixth,* the grade rod. The right-hand page has a central column, in which, and opposite the number of the station, is recorded the center depth of the section, marked + or −, to indicate cut or fill, as the case may require. To the right of this are recorded the notes of that portion of the section which lies on the right of the center line, as the line was run, and to the left, the notes of the left side. The distance from the center to each point noted is recorded as the numerator of a fraction, and the cut or fill at the point as the denominator prefixed by a + or −, as the case may require. The denominator for a grade point is zero. The numbers of the stations should increase *up* the page, as in a transit book, so that there may be no confusion as to the right and left side of the line. The several points being noted in order as they occur from the center outwards, the notes farthest from the center of the page usually appertain to the slope stakes; but in case the cross-profile is extended beyond the slope stake, the note of the latter should be surrounded by a circle to distinguish it. The following form is a specimen of a right-hand page, with the first column only of the left-hand page:

Sta.	*L*	*C*	*R*
12	$\frac{9.8}{-1.2}$	−3.0	$\frac{12.8}{-3.2}$
+40	$\frac{8}{0}$	−2.6	$\frac{11.3}{-2.2}$
11	$\frac{14.2}{+2.8}$ $\frac{4}{0}$	−0.8	$\frac{10.7}{-1.8}$
+94	$\frac{14.5}{+3.0}$	0.0	$\frac{9.8}{-1.2}$
+68	$\frac{16.0}{+4.0}$ $\frac{7.0}{+2.0}$	+1.4	$\frac{10}{0}$
10	$\frac{20.5}{+7.0}$ $\frac{12.0}{+4.6}$	+3.0	$\frac{13.6}{+2.4}$

CHAPTER XII

CALCULATION OF EARTHWORK

281. The first step toward finding the cubical content of an excavation is to divide it into a number of prismoids by several cross-sections.

A prismoid is a solid having plane parallel bases or ends, and bounded on the sides either by planes, or by such surfaces as may be generated by a right line moving continuously along the edges of the bases as directrices.

The positions of the cross-sections must be so selected that the solid included between any two consecutive sections may be a prismoid as nearly as possible. Upon a tangent the roadbed and side-slopes are planes, so that the prismoidal character of a given solid depends upon the shape of the natural surface. When the natural surface is a plane, the sections are taken only at the regular stations, 100 feet apart; when it is curved, warped, irregular, or broken, the sections must be more numerous, so that the surface limited by any two shall be composed substantially of right-lined elements extending from one section to the other.

If two end sections of a prismoid are somewhat similar, we infer that the corresponding points are connected by right-lined elements, forming in each case the axis of a ridge or of a hollow. If one section has less breaks than the next, some of these ridges or hollows must vanish; and in order that the solid may be a prismoid, they must vanish in the section of least breaks; therefore a cross-section must be taken on the ground through the point where each ridge or hollow vanishes, and the distance of that point from the center line noted, so that it may be coupled with the proper point in the next section for exact calculation of content.

When ridges or hollows run diagonally across the line of road, cross-sections must be taken where they are intersected not only by the center line, but also by the side slopes; that is, sections must be taken so that a side stake may stand on top of each ridge and at bottom of each hollow. In case the center line intersects at right angles a retaining wall or other vertical surface, two cross-sections are required at the same point, one at top and the other at base of wall, in order to furnish the data necessary to calculate the content each way from the vertical surface. (See § 253.)

Every thorough cut terminates in either side-hill cutting, a pyramid, or a wedge; the latter happens only when the contour of the natural surface is at right angles to the line of road. Sections should always be taken through the points where the edges of the roadbed meet the surface, as these are the points of separation between thorough and side-hill work. An illustration of such a case is given in Fig. 121. This sketch conforms approximately to the notes taken in § 260. In side-hill work the foregoing rules apply as well, but sections will generally be more numerous than in thorough cuts. The same rules apply also to embankment, but as grading is preferably paid for in excavation, the same precision in determining the quantities in embankment is not usually necessary.

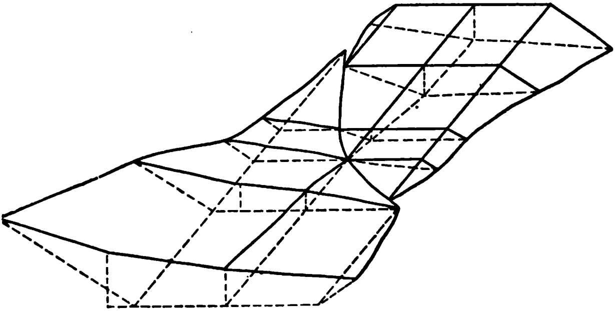

FIG. 121.

262. Formulas for Sectional Areas.

Let b = base of section or width of roadbed;

s = slope ratio = $\dfrac{\text{horizontal}}{\text{vertical}}$;

d = depth at center stake;

h, k = depths at side stakes;

m, n = horizontal distances from center to side stakes.

For ground level transversely, the section is a trapezoid and the area is

$$A = bd + sd^2 \tag{336}$$

or directly from the field notes,

$$A = \tfrac{1}{2}(b + m + n)d \tag{337}$$

For ground of uniform transverse slope between slope stakes, Fig. 122, the section consists of the trapezoid $ABOE$ and the triangle EOD. Hence

$$A = \tfrac{1}{2}(AB + EO)EN + \tfrac{1}{2}EO(DH - EN)$$
$$A = \tfrac{1}{2}(AB.EN + EO.DH)$$

or

$$A = \tfrac{1}{2}[bh + k(b + 2sh)]$$

also

$$A = \tfrac{1}{2}[bk + h(b + 2sk)] \tag{338}$$

From which also

$$A = \tfrac{1}{2}bh + mk$$

and

$$A = \tfrac{1}{2}bk + nh \tag{339}$$

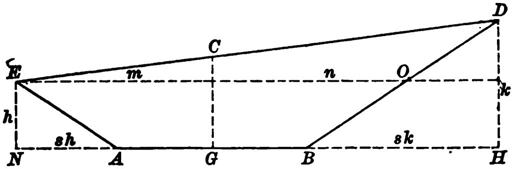

Fig. 122.

These formulas are independent of the center depth. They are convenient for calculating the area of a plotted section having an irregular surface after the surface line has been averaged by stretching a silk thread over it. The points where the thread intersects the slope lines determine the values of h, k, m, and n respectively.

When the ground has uniform slopes transversely from the center to the side stakes: Fig. 123. If in the diagram we draw EG and DG, the section will be divided into four triangles, *two* having the common base $CG = d$ and respective heights $GN = m$ and $GH = n$, and *two* having the equal bases $AG = GB = \tfrac{1}{2}b$ and the respective heights $EN = h$ and $DH = k$. Hence we have for the area of section

$$A = \tfrac{1}{2}d(m + n) + \tfrac{1}{4}b(h + k) \tag{340}$$

Otherwise, if the slope lines are produced to meet below grade at P, then $GP = \frac{AG}{s} = \frac{b}{2s}$. The area of $CEPD$ is $\frac{1}{2}CP \times NH = \frac{1}{2}\left(d + \frac{b}{2s}\right)(m + n)$. The area of ABP is $AG \times GP = \frac{b^2}{4s}$. Hence we have for the area of the section

$$A = \frac{1}{2}\left(d + \frac{b}{2s}\right)(m + n) - \frac{b^2}{4s} \qquad (341)$$

Both these formulas are convenient, and as the values of the several letters can be substituted directly from the field notes, it is unnecessary to plot such sections.

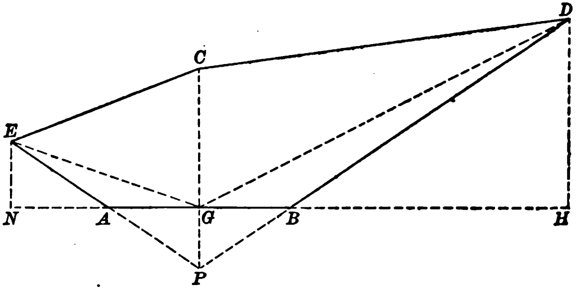

FIG. 123.

The triangle ABP is called the *grade triangle*. Computation by (341) is somewhat more rapid than by (340), since $\frac{b}{2s}$ and $\frac{b^2}{4s}$ are constants for the same base and side slope.

Where elevations are taken at points immediately above A and B, in Fig. 123, in addition to those at C, D, and E, the section is called *five-level*. The area may be found as explained for Fig. 124.

When the surface of the ground is irregular the plotted section may be divided into trapezoids by verticals drawn through the surface breaks and at the slope stakes. The area of the section is then the sum of the areas of these trapezoids less that of the two outside triangles. Fig. 124.

Or the section may be further divided into triangles, one *vertical line* serving as the base of two triangles which are computed in pairs. From the sum of all the areas it may or may not be necessary to deduct the area of one or both of the outside triangles. With either of these methods the dimensions used are taken directly from the field notes, and many times it is not necessary to plot the section.

But when the breaks are numerous the number of parts to be calculated may be greatly reduced by the use of one or more averaging lines stretched over the surface line of the plotted section and noting the points where they intersect the center line and the side lines. Such points then govern the section in place of the original notes, and the section is thus graphically reduced to a two-level or three-level section, as the case may require, with the same ultimate results in area or solidity.

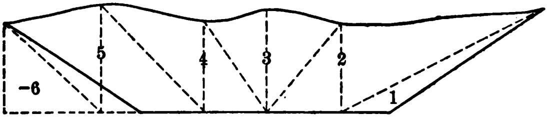

FIG. 124.

The *planimeter* is sometimes used in determining the areas of irregular sections. Its use will prove economical in case of double-tracking work. It should never be employed where disputes are likely to arise.

In side-hill work, the section may also be divided into triangles, and the area found as with irregular sections.

Valuation work. In work on state or federal valuation of existing railways, it is often necessary to estimate volumes where the original profiles and notes of the cross-section have been either lost or destroyed. Under such conditions, the side heights h and k, together with the width of roadbed, b, and the slope ratio s, are obtained from direct measurements in the field. No information as to the condition of the original surface is available, and consequently it is considered as sloping uniformly between slope stakes. When the existing roadbed is level, eqs. (338) or (339) will apply. If the roadbed is not level transversly, the most satisfactory method is to use a level line at the top of rail or at the top of tie as a *reference* line. The area between this level *line and the line joining* the slope stakes may then be found, and the resultant area obtained by adding or subtracting the proper amounts for subgrade level.

263. The volume of a solid may be found either by the *mean area formula* or by the *prismoidal formula*. The former does not in general give the true volume, while the latter does.

The mean area formula is

$$S = \frac{l}{27}\frac{(A + A')}{2} \tag{342}$$

where S = the volume in cubic yards between two adjacent sections, l = the length in feet, A and A' = the areas at the two parallel ends.

Equation (342) may also be expressed as

$$S = \frac{A}{27}\frac{l}{2} + \frac{A'}{27}\frac{l}{2}$$

This is based on the assumption that each area extends a distance of $\frac{1}{2}l$.

The *prismoidal formula* is

$$S = \frac{l}{6 \times 27}(A + 4M + A') \tag{343}$$

where M = the area of a section midway between the ends, and the others are as before. This area is not a mean of the other two, but the linear dimensions of the mid-section are means of the corresponding dimensions of the end sections; from which, therefore, the area of the mid-section may be computed.

Computation of Volumes. The labor of calculating the prismoidal volumes may, in many instances, be lessened by first using eq. (342) and then applying a correction, called the *prismoidal correction.* The result will be the same as if eq. (343) were used. This correction formula will now be found.

264. Prismoidal Correction Formulas. Let C = the difference between results in computing the contents of a solid by mean areas and by the prismoidal formula.

Then

$$C = S_E - S_P \tag{344}$$

where

$$S_E = \text{the mean area volume,}$$

and

$$S_P = \text{the prismoidal volume.}$$

From eqs. (342) and (343) there results

$$C = \frac{l}{3 \times 27}(A - 2M + A') \qquad (345)$$

which is the general formula for the prismoidal correction.

Triangular Section. Fig. 125. When the bases of a solid are triangles, $A = \frac{1}{2}bk$; $A' = \frac{1}{2}b'k'$; and

$$M = \frac{1}{2}\left[\left(\frac{b + b'}{2}\right)\left(\frac{k + k'}{2}\right)\right]$$

Substituting these quantities in eq. (345) and collecting terms there results

$$C = \frac{l}{12 \times 27}(b - b')(k - k') \qquad (346)$$

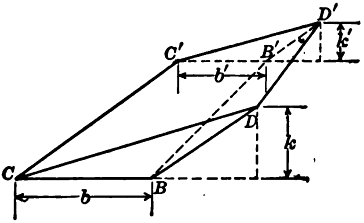

FIG. 125.

The prismoidal volume may in this case be obtained directly from eq. (343) rather than by use of eqs. (342) and (346). By substituting in eq. (343) the values of A, A', and M just found, and collecting terms, there results

$$S_p = \frac{l}{12 \times 27}[(2b + b')k + (2b' + b)k']$$

Three-level Sections. A solid whose bases are three-level sections, may be divided into triangular prisms, and the mean area volume of each prism found. For the prismoidal corrections, eq. (346) may be applied to each triangular prism. Referring to Fig. 123, the correction for the triangular prisms between *AGE*, *BGD* and similar triangles at the second station will be zero, since b and b' are equal. The correction for the two triangular prisms bounded by

GEC, *GDC* and similar triangles at the second statio be

$$\frac{l}{12 \times 27}(d - d')(n - n')$$

and

$$\frac{l}{12 \times 27}(d - d')(m - m')$$

or for the part *EGDC* it will be

$$C = \frac{l}{12 \times 27}(d - d')[(m + n) - (m' + n')]$$

Designating $(m + n)$ by D, and $(m' + n')$ by D' this bec

$$C = \frac{l}{12 \times 27}(d - d')(D - D')$$

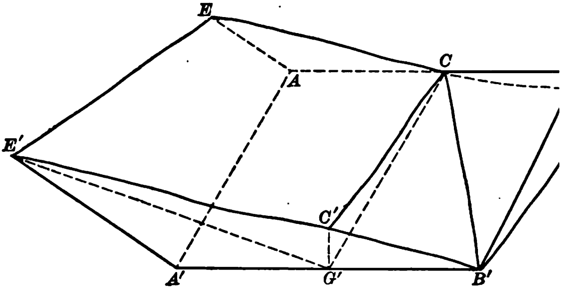

FIG. 126.

Again by substituting the values of A, A' and M eq. (341) in eq. (345), the same result will be obtained.

When C as found from eq. (348) is positive, it sig that S_E is larger than S_P, and *vice versa*. Equation may be written $S_P = S_E - C$.

A general rule may be formulated as follows:

The prismoidal correction in general is to be subtr from a volume computed by the mean area method. only exception is when, in the end sections, the greater c depth is combined with a smaller distance between stakes; a case of rare occurrence, but which changes the *of one factor* in eq. (348) and therefore of C. C is then ded.

265. Application of the Prismoidal Correction. In the case of *three-level sections*, or with wedges, the data from the field notes are applied directly in eq. (348).

Passing from Cut to Fill. Figs. 126 and 127 approximately illustrate part of the notes given in § 260.

The volumes between stations 10 + 68 and 10 + 94 are represented in Fig. 126. The solid $B'CBD$ is a triangular pyramid, the volume of which is equal to one third the product of the area of the base and altitude, and the prismoidal correction is zero. The correction for the solid $A'B'C'E'EAC$ as found from eq. (347) is

$$C = \frac{l}{12 \times 27}(d - 0)[(m + n) - (m' + 0)]$$

Side-hill Work. Between stations 10 + 94 and 11, Fig. 127, there is a triangular prism on the left (omitting from consideration the reading at the point 7 feet from the center) and a prismoid on the right. The correction for this prism is given by eq. (346). The prismoidal correction for the prismoid on the right is found from eq. (347) which gives

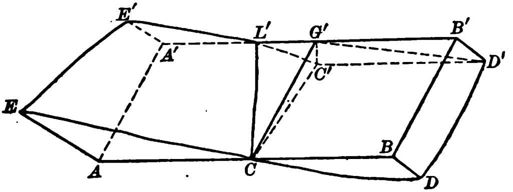

FIG. 127.

$$C = \frac{l}{12 \times 27}(0 - d')[(n + 0) - (n' + G'L')]$$

The sign of C in this equation will be positive, thus showing that the order in which the sections are taken is immaterial.

Irregular Sections. The volume between two irregular sections may be found either by the prismoidal formula or by the mean-area formula. In the latter case, there are several approximate ways of determining the prismoidal correction. The two in greatest favor are:

(1) When the ground is only slightly irregular, neglect

the intermediate points, and for the *correction*, treat tl tions as three-level.

(2) Plot the sections on cross-section paper and lines which will form an approximation to the thre sections. Find d and D for each section and use eq. (3

The first method will, in general, give results suffi close. Personal preference governs largely the cho other methods.

266. Correction of Earthwork for Curva

The preceding calculations are based on the assumptio the center line is straight, with cross-sections at right to it. When an excavation is on a curve, the cross-se being in radial planes, are inclined to each other, s the condition of a prismoid is not exactly fulfilled. I the property of Guldinus, if any plane area is made to r about an axis in the same plane, the volume of a soli erated by the area is equal to that of a prism having equal to the given area, and a height equal to the len path described by the center of gravity of the area. path, being the arc of a circle, is proportional to the drawn to the center of gravity. If therefore a cross-s is symmetrical with respect to the center line, the p the center of gravity is equal to the measured length center line, and no correction for curvature is required

But when the ground is inclined transversely, the of gravity is one side of the center line, and its path, if w ceive it to sweep around the curve, from one end of moid to the other, is longer or shorter than the di measured on the center line, according as the center of g is outside or inside of the center-line curve.

Let C = correction in cubic yards due to curvature;
S = cubic yards as obtained by prismoidal form
R = radius of center line;
e = eccentricity of center of gravity of section;
= horizontal distance from center line to cer gravity.

We then have the proportion,

$$S \pm C : S :: R \pm e : R$$

$$C = \frac{Se}{R}$$

As the sections of a solid are seldom similar and equal, we shall usually have a different value of e for every section, from which, however, a mean average value may be deduced, and used in the above formula. But it will be more convenient to correct the areas themselves for eccentricity before finding S, which will then require no correction. For the same result will ensue whether we multiply S by $\frac{e}{R}$, or multiply one of the component factors of S by the same ratio.

If then c = correction of area in square feet to eccentricity, we have at once

$$c = \frac{Ae}{R}$$

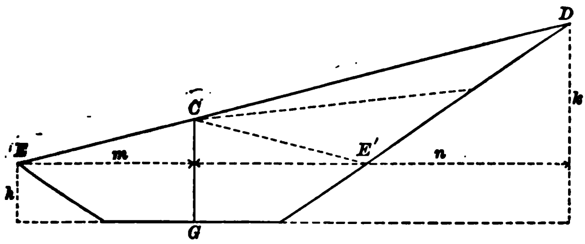

FIG. 128.

and the corrected area equals $A \pm c$ according as the cut is deeper on the outside or inside of the curve. Each area used in determining the solid contents should, on a curve, be first corrected in this manner.

To find the value of e for any three-level section. Fig. 128.

Find the areas either side of the center line separately, calling them H and K, and take their sum and difference. Using the same notation as in § 262, $H = \frac{1}{2}md + \frac{1}{4}bh$, $K = \frac{1}{2}nd + \frac{1}{4}bk$, and $H + K = A$.

$$K - H = \frac{1}{2}d(n - m) + \frac{1}{4}b(k - h)$$

In the figure draw CE' equal to CE, and the triangle $CE'D$ will represent the area $(K - H)$. Bisect the side $E'D$, and draw a line from C to the middle point. Then the center of gravity of the triangle will be on this line at two thirds its length from C, and the horizontal distance of the center of gravity from C is $\frac{2}{3} \times \frac{1}{2}(m + n) = \frac{1}{3}(m + n)$. The center of gravity of the remainder of the section is on the center line CG, so that the value of e is found from the proportion

$$e : \tfrac{1}{3}(n + m) :: K - H : A$$

$$\therefore \qquad e = \frac{n + m}{3A}(K - H)$$

$$\text{Hence} \quad c = \frac{Ae}{R} = \frac{n + m}{3R}[\tfrac{1}{2}d(n - m) + \tfrac{1}{4}b(k - h)] \qquad (350)$$

Sections which are more irregular may be plotted and reduced by averaging lines to three-level sections, in order that the formula may be applied. If the ground is so irregular as to require the computation of the middle section, the correction c should be found and applied to this area (M) also before introducing it into the prismoidal formula. As the correction for curvature is always relatively small, it is usually ignored in practice for thorough cuts, except where deep cuttings with steep transverse slope occur on sharp curves.

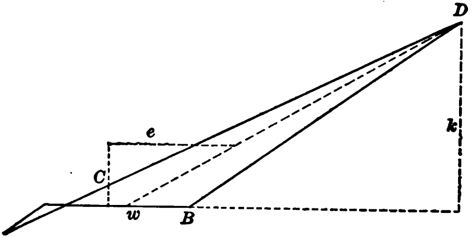

FIG. 129.

The correction is of more importance relatively in **side-hill work** as the center of gravity of the section is more remote from the center line. Let the section be reduced to a triangle by an averaging line (Fig. 129), and w be the base of the triangle formed by the averaging line. The *center of gravity* is at one third the horizontal distance from *the middle point* of w to the side stake D, while the distance of this middle point from the center stake C is evidently $\frac{1}{2}b - \frac{1}{2}w$.

Hence

$$e = \tfrac{1}{2}b - \tfrac{1}{2}w + \tfrac{1}{3}[n - (\tfrac{1}{2}b - \tfrac{1}{2}w)]$$

or

$$e = \tfrac{1}{3}(b + n - w)$$

and

$$c = \frac{Ae}{R} = \frac{b + n - w}{3R} \times \frac{wk}{2} \qquad (351)$$

The correction c will be *plus* or *minus* as before explained. This formula applies to all side-hill triangular sections, whether there be cut or fill at the center stake.

Example 1.—Thorough cut; base 20; slopes 1½ : 1.

$$l = 100;\ 8° \text{ curve, left};\ R = 716.78$$

Notes. $\quad A.\dfrac{16}{+4} \quad +12 \quad \dfrac{58}{+32}$

$\qquad\qquad A'.\dfrac{13}{+2} \quad +8 \quad \dfrac{40}{+20}$

Then $K = \frac{1}{2} \times 58 \times 12 + \frac{1}{4} \times 20 \times 32 = 508$

$\qquad H = \frac{1}{2} \times 16 \times 12 + \frac{1}{4} \times 20 \times 4 = 116 \therefore A = 624$

$K - H = \qquad 392$

Eq. (350) $\quad c = \dfrac{16 + 58}{3 \times 716.78}\, 392 = \qquad 13.49$

$\qquad (A + c) \quad 637.49$

$K' = \frac{1}{2} \times 40 \times 8 + \frac{1}{4} \times 20 \times 20 = 260$

$H' = \frac{1}{2} \times 13 \times 8 + \frac{1}{4} \times 20 \times 2 = 62 \therefore A' = 322$

$K - H = \qquad 198$

$\quad c' = \dfrac{13 + 40}{3 \times 716.78}\, 198 = \qquad 4.87$

$\qquad (A' + c') = 326.87$

From which we obtain S = 1758 cu. yds.—*Ans.*

Without correction we have 1726 cu. yds.

Showing a difference of 32 cu. yds.

Had the curve been to the *right* with same notes, c would *have been minus,* and S would = 1694.

Example 2.—Side-hill cut; base 20; slopes $1\frac{1}{2} : 1$
$l = 60$; 10° curve, right; $R = 573.69$

Notes
$$\frac{6}{0} \quad +2.8 \quad \frac{40}{+20}$$
$$-0.8 \quad +\frac{2}{0.0} \quad \frac{37}{+18}$$

$$A = \tfrac{1}{2} \times 16 \times 20 = \qquad 160$$

Eq. (351)
$$c = \frac{20 + 40 - 16}{3 \times 573.69} 160 = \qquad 3.58$$

$$(A - c) = 156.42$$

$$A' = \tfrac{1}{2} \times 8 + 18 = \qquad 72$$

$$c' = \frac{20 + 37 - 8}{3 \times 573.69} 72 = \qquad 2.05$$

$$(A' - c) = \ 69.95$$

Hence $S = 248$ cu. yds.
Without correction S would $= 255$ cu. yds.

Difference 7 cu. yds.

267. Any isolated mass of rock or earth which occurs within the limits of the slope stakes, but not included in the regular notes, is separately measured and noted, so that its contents may be computed and added to the sum of the same material found in the cross-sections.

268. Borrow-pits.—When the excavations will not suffice to complete the embankments, material may be taken from other localities, termed *borrow-pits*. These should be staked out by the engineer and their contents calculated, unless the contractor is to be paid for work by embankment measurements. A number of cross profiles are taken of the original surface, and (on the same lines) of the bottom of the pit after it is excavated, which furnish the depth of cutting at each required point. Borrow-pits should be regularly excavated so that they may not present an unsightly appearance when abandoned. Borrow-pits may be avoided by widening the cut uniformly at the time it is staked out, so that it may furnish sufficient material; *provided the material is* suitable, the embankment accessible, and the *stance not too* great. When the excavation is in excess, the surplus material should be uniformly distributed by widening the adjacent embankments, if possible; otherwise it is deposited at convenient places indicated by the engineer and is said to be *wasted.*

269. Vertical Prisms. Material excavated from borrow pits may be measured also by first staking off the field into rectangles of suitable size and taking the elevation of surface at every stake. If convenient some triangles may be laid out where boundaries are oblique. All lines should be carefully referenced. After excavation the intersections are relocated and their elevations taken; the difference in elevation being the depth of cut at each point. Thus the entire mass is subdivided into vertical prisms, truncated or otherwise, the cubic contents of which may be easily computed. To facilitate the reduction to cubic yards it is customary to choose such dimensions as will make the area of each prism base some multiple of 27 square feet.

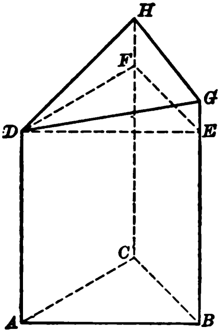

FIG. 130.

The proper size of rectangle to be used depends upon the natural surface which should give practically right lines to prism ends. Shallow work calls for larger rectangles because so soon excavated.

270. *To find the volume of a truncated triangular prism, whose horizontal section is a triangle of given area* A. Fig. 130.

Let h_1, h_2, *and* h_3, denote the heights AD, BG and C

Through the lowest point D of the upper face, draw a horizontal plane DEF, cutting off the pyramid $DEGHF$, whose base is a trapezoid, and whose altitude is the perpendicular distance from D to FE and designated by a.

The volume of the pyramid $DEGHF$

$$\tfrac{1}{3}a \times FEGH = \tfrac{1}{3}a \times \tfrac{1}{2}(EG + FH)FE = \tfrac{1}{3}A(EG + FH),$$

since

$\tfrac{1}{2}a \times FE = A.$

By geometry, the volume of a prism, not truncated $= Ah = Ah_1$ in this case. The volume of the truncated prism $ABCDGH$ = the sum of the two parts

$$= Ah_1 + \tfrac{1}{3}A(EG + FH)$$

$$= A \times \tfrac{1}{3}[h_1 + (h_1 + EG) + (h_1 + FH)]$$

or, in cubic yards,

$$S = \frac{A}{27}\,\frac{h_1 + h_2 + h_3}{3} \qquad (352)$$

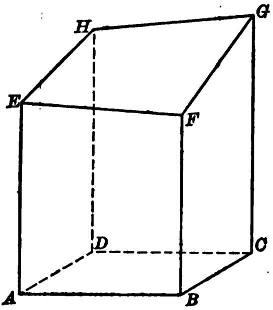

FIG. 131.

271. *To find the volume of a* **truncated rectangular prism,** *whose horizontal section is a rectangle of area A.* Fig. 131.

The end area formula gives the correct cubic content, since in this figure the prismoidal correction is zero, provided that, the top and bottom ends, whether plane or warped, are bounded by right lines.

Let the heights AE, BF, CG, and DH be represented by h_2, h_3, and h_4, and the area ABCD by A.

Now the figures $ADHE$ and $BCGF$ may be considered as bases of the solid with the altitude as $AB = DC$.

The mean area volume

$$S = \frac{AB\,(\text{area } ADHE + \text{area } BCGF)}{2 \times 27}$$

$$= \frac{1}{2} \cdot \frac{AB}{27} \left[\left(\frac{h_1 + h_4}{2} \right) AD + \left(\frac{h_2 + h_3}{2} \right) BC \right]$$

$$= \frac{1}{4} \cdot \frac{AB}{27} (h_1 + h_2 + h_3 + h_4) BC$$

But

$$AB \times BC = A$$

$$\therefore \qquad S = \frac{A}{27} \left(\frac{h_1 + h_2 + h_3 + h_4}{4} \right) \qquad (353)$$

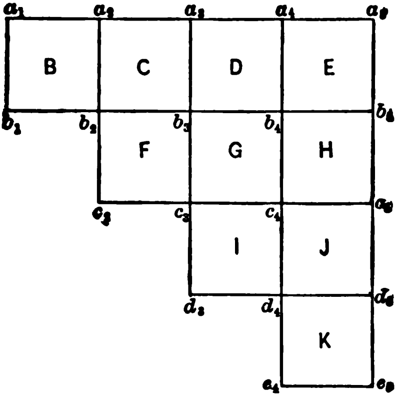

FIG. 132.

272. Method by Unit Areas. When a number of prisms contiguous to each other have the same horizontal section, A, their total cubic content may be obtained by a single formula. For since by eq. (353) the four-corner depths of a prism are to be added together, it is evident that the depth at any corner whatever will be taken into account as many times as the number of rectangles which meet at that point.

Thus in Fig. 132 the depths at the corners a_1, b_1, c_2, d_3, etc., *enter into the volume* of one prism only; while those at a_2, a_3, a_4, etc., affect two prisms each; and those at b_2, c_3, d_4, etc., affect three prisms each, and so on.

Therefore if we let s_1 = the sum of all depths used but once, s_2 = the sum of all depths used twice, s_3 = the sum of all depths used three times, and s_4 = the sum of all depths used four times, we shall have for the total content of all prisms considered,

$$S_{\text{total}} = A\,\frac{s_1 + 2s_2 + 3s_3 + 4s_4}{4 \times 27} \tag{354}$$

Marginal masses, not included in this system, must be measured and computed separately.

273. The foregoing method of prisms is not well adapted to steep hillsides or bluff banks from which material is to be borrowed. In such cases if the pit is apart from the road, a base line is staked out in the general direction of the contour, and frequent cross-sections are taken to define the shape of the pit before and after excavation.

If the needed material is to be taken from the regular cuts the regular cross-sections are extended beyond the slope stakes and other stakes are set to mark the limit of the pit, and the quantities are computed in the usual manner.

But if the roadbed consists of a long shallow embankment made of material scraped up at random from either side, the quantities should be measured and paid for in the finished fill, under the terms of the contract, without reference to the borrow-pits.

CHAPTER XIII

EARTHWORK TABLES

274. The labor involved in the calculation of earthwork may be greatly reduced by the use of earthwork tables.

The common forms of tables are those for level sections; three-level sections; triangular prisms; and prismoidal corrections.

275. Level-sections. For purposes of preliminary estimates, tables computed on the assumption that the ground is level transversely are quite sufficient. The volume of any one solid may be greatly in error, but it is surprising how nearly the total of the preliminary volumes on an extended line, will compare with the final volumes obtained after cross-sectioning. The center cut or fill is taken from the profile.

The area of a level-section is expressed by eq. (336) which is

$$A = bd + sd^2$$

The volume in cubic yards for a length of 100 feet is

$$S = \frac{100}{27}(bd + sd^2) \tag{355}$$

Table XXX was computed by this formula with such values of b and s as are in common use.

A section affects the volumes for 50 feet each side of itself. For preliminary estimates, the volumes may remain as taken from the table in which case, where there are whole stations, the volume extends from plus 50 to plus 50. In the construction of the mass diagram (see Chapter XV) the volume for a *50-foot length* should be added to that for a preceding 50-foot length, and again to a succeeding 50-foot length, in order to give the amounts between adjacent whole stations. For substations the proper percentage is taken.

276. Tables of Triangular Prisms. The volume of a triangular prism is equal to the product of the area of the base and the altitude or

$$S = \frac{bal}{2 \times 27} \text{ in cubic yards.} \qquad (356)$$

where b and a are the base and altitude of the triangular section, and l is the altitude of the prism.

For a 50-foot length this equation becomes

$$S = \frac{50}{54}ba \qquad (357)$$

Table XXXI has been computed from eq. (357) for different values of b and a. In this table b is considered as "width" and a as "height," but these terms may be used interchangeably when convenient, since the product is the same.

The volume of any solid which can be divided into triangular prisms may be found from this table.

277. Tables of Three-level Sections. The area of a three-level section may be found by the two methods given in § 262. In the first method the section is divided into four triangles. The volume in cubic yards for prisms of length 50 feet will be

$$S_E = \frac{50}{54}d(m+n) + \frac{50}{54}\tfrac{1}{2}b(h+k) \qquad (358)$$

It is to be noted that the terms on the right-hand side of this equation are similar to eq. (357) for the volume of a triangular prism. Consequently Table XXXI may be used for the products of the parts and the constant $\frac{50}{54}$.

In the second method of § 262, the area is made up of two triangles minus the grade triangle. The volume for length 50 will be

$$S_E = \frac{50}{54}\left(d + \frac{b}{2s}\right)(m + n) - \frac{50}{54}\frac{b^2}{2s} \qquad (359)$$

Table XXXI of Triangular Prisms is also used for this method.

Extension of Level-section Table. Where the center cuts or fills are taken from the profile for a preliminary estimate and the quantities obtained from Table XXX, these may be corrected by use of Table XXXI after the cross-sections have been taken, which give the side heights. These corrections are illustrated by the triangular prisms with bases *DCD'* and *CEE'* in Fig. 133. The base of each triangle is equal to $\frac{1}{2}b + sd$, and the altitudes of the triangles are the differences between the center height and each side height. If a side height is less than the center height, the correction is to be subtracted and if greater, added. The products of the bases and altitudes of the triangles and the constant $\frac{50}{54}$ give the correct volumes on each side.

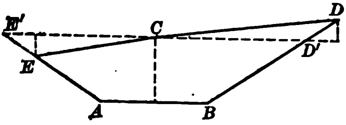

FIG. 133.

It should be noted that Table XXXI is for 50-foot lengths, while Table XXX is for 100-foot lengths.

278. Tables for Irregular Sections. A table of triangular prisms is suitable for finding the volumes of earthwork solids with irregular sections for bases. The sections may be divided into triangles as in Fig. 134, and the bases and altitudes of each triangle found. Equation (357) applies to each partial volume, and the total volume is the sum of the parts. Table XXXI is available for this work.

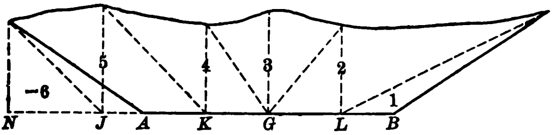

FIG. 134.

279. Prismoidal Correction Table. Where the mean area formula is used for finding the volume of a solid, as is *the case with the* tables described above, the prismoid correction must be applied to give the true volume. Eq. (348) gives the value of this correction. For a distance between sections of 100 feet and for the result in cubic yards, this equation becomes

$$C = \frac{1}{3.24}(d - d')(D - D') \qquad (360)$$

Table XXXII has been computed from this equation for different values of $(d - d')$ and $(D - D')$. The correction is applied as explained in §§ 264 and 265.

280. Example. Use of Tables XXXI and XXXII.

$$\text{Notes: Sta. 3} \quad \frac{21.0}{+8.0} \quad +\ 7.3 \quad \frac{19.2}{+6.8}$$

$$\text{Sta. 2} \quad \frac{17.1}{+5.4} \quad +\ 4.5 \quad \frac{15\ 0}{+4.0}$$

$$b = 18, \quad s = 1\tfrac{1}{2} \text{ to } 1$$

The plus sign merely indicates cut and is not considered in the computations.

First, by the method based on eq. (358).

For station 2, $d = 4.5$; $m + n = 32.1$; $\frac{1}{2}b = 9.0$; and $h + k = 9.4$.

From Table XXXI,

Opposite H'g't.	4.5	under 3	take 10	× 12.500	= 125.000
		" 2	" 1	× 8.333	= 8.333
		" 1	" $\frac{1}{10}$	× 4.167	= .417
Opposite H'g't.	9.4	" 9	" 1	× 78.333	= 78.333

Total volume for length of 50 feet = 212.083

For station 3, $d = 7.3$; $m + n = 40.2$; $\frac{1}{2}b = 9.0$; and $h + k = 14.8$.

From Table XXXI.

Opposite H'g't.	7.3	under 4	take 10	× 27.037	= 270.370
		" 2	" $\frac{1}{10}$	× 13.519	= 1.352
Opposite H'g't.	14.8	" 9	" 1	× 123.333	= 123.333

Total volume for length of 50 feet = 395.056

The quantities may be obtained from the tables some-[illegible]t *more easily* by not strictly adhering to the terms "[illegible]*ht*" *and* "width."

Consequently the mean area volume between stations 2 and 3 is

$$S_E = 212.083 + 395.056 = 607.139$$

The value of C may be found from Table XXXII, which is based on eq. (360).

Now $d - d' = 2.8$, and $D - D' = 8.1$.
and

$$\frac{1}{3.24} \times 2.8 \times 8.1 = 7.000$$

$$\therefore \qquad S_P = S_E - C = 607.139 - 7.000 = 600.139$$

Second, by the method based on eq. (359).

Now $$\frac{b}{2s} = 6.0$$

For station 2, $d + \frac{b}{2s} = 10.5$ and $m + n = 32.1$

From Table XXXI,

$$\begin{array}{lllll} \text{Opposite H'g't. } 10\cdot5 \text{ under} & 3 & \text{take} & 10 \times 29.167 = & 291.670 \\ \qquad\qquad\qquad\quad `` & 2 & `` & 1 \times 19.444 = & 19.444 \\ \qquad\qquad\qquad\quad `` & 1 & `` & \frac{1}{10} \times 9.722 = & 0.972 \\ \hline & & & \text{Total} \quad = & 312.086 \end{array}$$

For the grade triangle there is subtracted $\frac{50}{54} \times 6 \times 18 = 100$, giving the resultant volume for section at station 2 as 212.086.

For station 3, $d + \frac{b}{2s} = 13.3$, and $m + n = 40.2$

From Table XXXI,

$$\begin{array}{lllll} \text{Opposite H'g't. } 13.3 \text{ under} & 4 & \text{take} & 10 \times 49.259 = & 492.590 \\ \qquad\qquad\qquad\quad `` & 2 & `` & \frac{1}{10} \times 24.630 = & 2.463 \\ \hline & & & \text{Total} \quad = & 495.053 \end{array}$$

The grade triangle portion (as above) = 100.

Then the volume of the prism with base equal to the section at station 3, is 395.053

∴ the mean area volume of the solid between stations 2 and 3 is 607.139.

The prismoidal correction is found in the same way as *the first method* and is 7.000

∴ the prismoidal volume = 607.139 − 7.000 = 60
This value is the same as that found in the first m

The tables are carried to three decimals, thus making more accurate when multiplied by 10. Work may be c out to any desired degree, decimals being omitted in th quantities.

Remark.—The second method is somewhat shorte the first, but where $\frac{b}{2s}$ is not in exact decimal, the obtained by the two will not exactly check.

CHAPTER XIV

EARTHWORK DIAGRAMS

281. General Principles. An equation of the first degree containing but two variables can be graphically represented by a straight line. Equations of the second or higher degree can only be represented by curves.

Consider the equation

$$y = ax \tag{361}$$

Where a is a constant and x and y the variables. This equation is that of a straight line and is represented by Fig. 135 for a certain value of a. Various values of x are laid off on the axis of x and the corresponding values of y are computed and laid off at right angles to OX. The line joining successive points will be represented by the line OA, which passes through the origin. Many problems can be solved from diagrams based on eq. (361), among which may be mentioned that for computing acres of right of way.

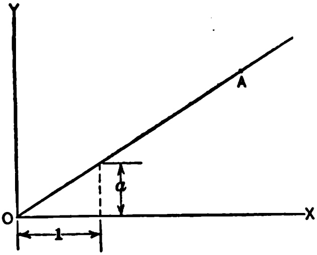

FIG. 135.

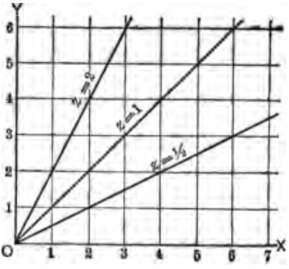

FIG. 136

Another equation is of the form

$$y = zx \tag{362}$$

Here there are three variables, but if we consider one as a constant, we may represent the equation graphically by substituting different values for the second variable, and solve the equation for the third quantity. Fig. 136 represents solutions of this equation for z of $\frac{1}{2}$, 1 and 2. When $z = \frac{1}{2}$ and $x = 1$, y will equal $\frac{1}{2}$; with $z = \frac{1}{2}$ and $x = 2$, y will equal 1, and so on. The $z = \frac{1}{2}$ line is thus found by laying off the quantities x and y along and at right angles to the axis of X. Cross-section paper may be used to advantage in work of this nature.

Other common equations are of the form

$$y = azx \tag{363}$$

$$y = a(z + b)(x + c)k \tag{364}$$

where a, b, c and k are constants. Diagrams for equations in form similar to both of these may be plotted as shown in Fig. 136.

Nearly all the equations for the computation of earthwork are similar in form to the last three equations above.

282. Triangular Prisms. The volume in cubic yards of a triangular prism of length 50 feet is $\frac{50}{54}ba$, where b and a represent the base and altitude of the triangular section. A diagram may be constructed for solving this equation. Different values of b and a may be substituted, giving corresponding volumes.

The table which follows will be of assistance in plotting the diagram. The particular values chosen for b were taken for simplicity in computing and plotting.

TABLE FOR PLOTTING PLATE I.—TRIANGULAR PRISMS

VALUES OF b

		0	5.4	10.8	16.2	21.6	27.0
Values of a	0	0	0	0	0	0	0
	1	0	5	10	15	20	25
	2	0	10	20	30	40	50
	3	0	15	30	45	60	75
	4	0	20	40	60	80	100
	5	0	25	50	75	100	125
	6	0	30	60	90	120	150
	7	0	35	70	105	140	175
	8	0	40	80	120	160	200
	9	0	45	90	135	180	225
	10	0	50	100	150	200	250

Cross-section paper may well be used for the diagram, but since the paper is liable to be more or less inaccurate as respects the ruling of the lines, several points in each line should be plotted considering the ruling of the paper as correct. The successive points are then connected.

A small reproduction of folding Plate I at the end of this volume is given in Fig. 137. Its construction is self-evident.

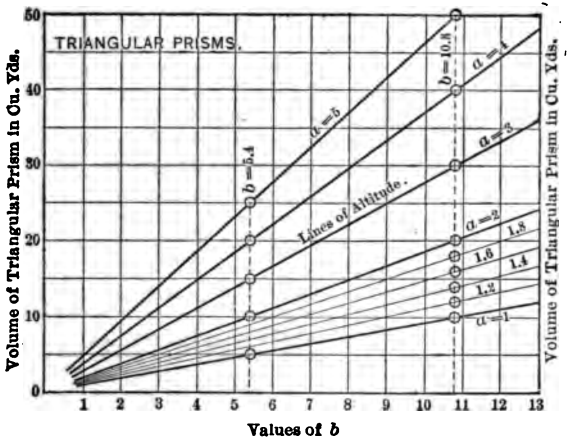

FIG. 137.

283. Use of the Diagram. Let the altitude and base of a triangle be 9.0 and 12.0 respectively. To find the volume of a triangular prism of length 50 feet. Go out to the $b = 12.0$ line and up to the $a = 9.0$ line. Read the volume as 100.0 cubic yards. This quantity, as previously noted, is the product of 9.0, 12.0, and $\frac{50}{54}$.

284. Diagram for Three-level Sections. The mean area volume of a solid of length 50 feet and with triangular base is found from eq. (359) which with D substituted for $(m + n)$ becomes

$$S = \frac{50}{54}\left(d + \frac{b}{2s}\right) D - \frac{50}{54}\frac{b^2}{2s}$$

Since b and s are constants in any particular case, there are only three variables in this equation, *d*, *D* and *S*. As previously explained, one of these values may be considered constant and *d* will be so taken. Having chosen the constant *d*, values of *S* may be found for different values of *D*. Here, as with triangular prisms, the work of plotting may be expedited by previously computing and arranging a table similar to the one below.

Plates II and III are plotted for bases of 20 and 16 feet, and side slopes of 1½ to 1. A separate diagram is necessary for each different combination of *b* and *s*. Values of *D* are laid off on the *x* axis, and those for *S* on the *y* axis. Inclined lines passing through successive points will be the lines representing the different values of *d*.

TABLE FOR PLOTTING PLATE II

DISTANCE BETWEEN SLOPE STAKES = *D*

Center Heights *d*	20.0	21.6	27.0	32.4	37.8	43.2	
	18.518	20.0	25.0	30.0	35.0	40.0	Const. Diff.
0	0	9.876	43.209	76.542	109.875	143.208	33.333
1	18.518	29.876	68.209	106.542	144.875	183.208	38.333
2	37.036	49.876	93.209	136.542	179.875	223.208	43.333
3	55.554	69.876	118.209	166.542	214.875	263.208	48.333
4	74.072	89.876	143.209	196.542	249.875	303.208	53.333
5	92.590	109.876	168.209	226 542	284.875	343.208	58.333
6	111.108	129.876	193.209	256.542	319.875	383.208	63.333
7	129.626	149.876	218.209	286 542	354.875	423.208	68.333
8	148.144	169.876	243.209	316.542	389.875	463.208	73.333
9	166.662	189.876	268.209	346.542	424.875	503.208	78.333
10	185.180	209.876	293.209	376.542	459.875	543.208	83.333

The labor involved in preparing a table for this work may be lessened by observing that certain parts of the above equation remain constant for successive changes in the variable quantities. Proper substitutions may be made in the general formula and the constant difference in solidities found. For instance, when $d = 1$ and $D = 20$,

$$S = \frac{50}{54}\left(1 + \frac{20}{3}\right)20 - \frac{50}{54}\frac{b^2}{2s}$$

Again when $d = 2$, and $D = 20$

$$S' = \frac{50}{54}\left(2 + \frac{20}{3}\right)20 - \frac{50}{54}\frac{b^2}{2s}$$

Subtracting S from S' there results

$$S' - S = \frac{50}{54} \times 20 = 18.518$$

The same difference will be found between $d = 2$, and $d = 3$.

Then if the next value of $D = 21.6$ is used with $d = 1$, and $d = 2$, the constant difference of 20 would be found.

It is advisable to solve the equation for all values of D when $d = 0$. The results are entered on the horizontal line of $d = 0$. After these quantities are found the numbers on the other horizontal lines may be obtained by use of the various constant differences.

A check crosswise of the table may also be obtained by solving the equation for S with different values of D. For instance, when $d = 0$ and $D = 21.6$

$$S = \frac{50}{54}\left(0 + \frac{20}{3}\right)21.6 - \frac{50}{54}\frac{b^2}{2s}$$

with $d = 0$, and $D = 27.0$.

$$S' = \frac{50}{54}\left(0 + \frac{20}{3}\right)27.0 - \frac{50}{54}\frac{b^2}{2s}$$

Then

$$S' - S = \frac{50}{54}\left(\frac{20}{3}\right)(27.0 - 21.6) = 33.333$$

Similarly for the differences in volumes when $d = 1$ with $D = 21.6$ and 27.0,

$$S'' - S = \frac{50}{54}\left(\frac{23}{3}\right)(27.0 - 21.6) = 38.333$$

A final check on the table should be made by substituting the largest values of d and D in the formula. In this case there results

$$S = \frac{50}{54}\left(10 + \frac{20}{3}\right)43.2 - \frac{50}{54}\frac{20^2}{3} = 543.208$$

This operation will check all quantities in the table.

Curve of Level Section.—On both plates II and III a curve of level section has been plotted. From eq. (331) we may find D for different values of d. Thus for Plate II when

$d = 0 \qquad D = 20.0$
$d = 0.4 \qquad D = 21.2$
$d = 1.4 \qquad D = 24.2$
$d = 2.4 \qquad D = 27.2$
$d = 6.4 \qquad D = 39.2$

The curve passing through the points having these coordinates is called the "curve of level section." The volumes for preliminary estimates may be obtained from this curve.

285. Use of the Diagram. The lines and quantities on Plate II are fully designated; an example will explain the proper method of procedure in determining volumes.

Example.—Cross-section notes are as follows:

Sta. 28	$\frac{16.0}{+4.0}$	$+2.4$	$\frac{11.8}{+1.2}$
Sta. 27	$\frac{19.0}{+6.0}$	$+3.0$	$\frac{13.6}{+2.4}$

For station 28, $d = 2.4$ and $D = 27.8$.

From Plate II, at the intersection of the lines $d = 2.4$ and $D = 27.8$ we obtain a volume of 110.1 cubic yards.

For station 27, $d = 3.0$ and $D = 32.6$.

At the intersection of the lines $d = 3.0$ and $D = 32.6$ we find a volume of 168.3 cubic yards.

Since the diagram gives results for 50-foot lengths, the total volume between the two stations is 110.1 + 168.3 = 278.4.

The result obtained for these same notes by tables is 278.26 cubic yards.

The prismoidal correction may be applied to this mean area volume. The amount of the correction is found similarly to the way explained in the next section.

286. Diagram for Prismoidal Corrections. The formula for the prismoidal correction has been previously deduced and is

$$C = \frac{1}{3.24}(d - d')(D - D') \tag{360}$$

The results are in cubic yards for a distance of 100 feet between sections.

Numerical substitutions for $(d - d')$ and $(D - D')$ may be made and the corresponding results found. It will be well to take $(d - d')$ as 0, 1, 2, 3, 4, 5, etc., and to take values of $(D - D')$ so that the corresponding C will be a whole number. For instance, when $(d - d') = 1$, the equation becomes $\frac{1}{3.24}(D - D')$, and convenient values of $(D - D')$ will be 0, 3.24, 6.48 and so on, giving C as 0, 1, 2, 3, 4, etc.

Similarly with $(d - d')$, taken as 2, 3, 4, etc. Likewise the equations of other $(d - d')$ lines may be found; convenient substitutions of $(D - D')$ made, and a table arranged for plotting the diagram.

TABLE FOR PLOTTING PLATE IV

$d-d'$	0	3.24	6.48	9.72	12.96	16.20	19.44	22.68	25.92	$D-D'$
0	0	0	0	0	0	0	0	0	0	
1	0	1	2	3	4	5	6	7	8	
2	0	2	4	6	8	10	12	14	16	
3	0	3	6	9	12	15	18	21	24	
4	0	4	8	12	16	20	24	28	32	
5	0	5	10	15	20	25	30	35	40	
6	0	6	12	18	24	30	36	42	48	
7	0	7	14	21	28	35	42	49	56	
8	0	8	16	24	32	40	48	56	64	
9	0	9	18	27	36	45	54	63	72	
10	0	10	20	30	40	50	60	70	80	

Plate IV at the back of this volume is the diagram for "Prismoidal Corrections." Lines intermediate between whole numbers of $(d - d')$ are plotted proportionally.

For finding prismoidal corrections for irregular sections one of the methods described in § 265 may be employed, the diagram being used after the preliminary quantities have been decided upon.

287. Use of the Diagram. Consider as an example that $d - d' = 4.0$ and $D - D' = 11.0$.

Going out for $D - D' = 11.0$ and following up to the line of $d - d' = 4.0$ we read the correction in cubic yards as 13.6. The value of C from computation to two decimal places is 13.58. When either $D - D'$ or $d - d'$ are too large for the limits of the diagram, they may be divided by some *even quantity*, as 2, 3, and so on, and a corres ing multiplication made after the correction has been obtained from the diagram.

288. Conclusion. The four plates placed at the end of this volume are necessarily reproduced at a small scale. On construction work a much larger scale should be adopted. Diagrams carefully made according to the principles here given, will not only give a high degree of precision, but their use will be conducive to speed in securing results.

The volume for any irregular section may be obtained by use of Plate I, provided the section is divided into triangles or trapezoids, as explained in the previous chapter.

CHAPTER XV

HAUL AND THE MASS DIAGRAM

289. Haul. The cost of removing excavated material, when the distance does not exceed a certain specified limit, is included in the price per cubic yard of the material as measured in the cutting. But when the material must be carried beyond this limit, the extra distance is paid for at a stipulated price per cubic yard, per 100 feet. The extra distance is known by the name of *haul,* and is to be computed by the engineer with respect to so much of the material as is affected by it.

The contractor is entitled to the benefit of all short hauls (less than the specified limit), and material so moved should not be averaged against that which is carried beyond the limit. Therefore, in all cuts, the material of which is all deposited within the limiting distance, no calculation of haul is to be made.

On the other hand, the company is entitled, in cases of long haul, to free transportation for that *portion* of the cutting, no one yard of which is carried beyond the specified limit. Therefore, this portion is first to be determined in respect to its extent; and the number of cubic yards contained in it is to be deducted from the total content of the cutting, before estimating the haul upon the remainder. Find on the profile of the line two points, one in excavation, and the other in embankment, such, that while the distance between them equals the specified limit, the included quantities of excavation and embankment shall just balance. These points are easily found by trial, with the aid of the cross-sections and calculated quantities, and become the starting points from which the haul of the remainder of the material is to be estimated.

Fig. 138 represents a cut and fill in profile. The distance *AB* is the *limit of free haul.* The materials taken from AO just make the fill *OB* and without charge for haul; but the haul of every cubic yard taken from *AC*, and carried to the fill *BD*, is subject to charge for the distance it is carried, less *AB*. It would be impossible to find the distance that each separate yard is carried, but we know from mechanics that the average distance for the entire number of yards is the distance between the centers of gravity of the cut *AC*, and of the fill *BD* which is made from it. If, therefore, *X* and *Y* represent the centers of gravity, the actual average haul is the sum of the distances $(AX + BY)$, and this (expressed in stations) multiplied by the number of cubic yards in the cut *AC*, gives the product to which the price for haul applies.

But the product of *AX* by the number of cubic yards in *AC* is equal to the sum of the products obtained by multiplying the contents of each prismoid in *AC* by the distance of its own center of gravity from *A*. The distance of the center of gravity of a prismoid from its mid-section is expressed by the formula

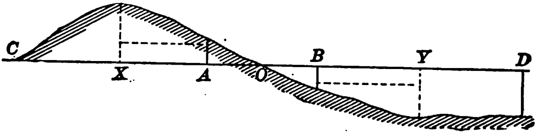

FIG. 138.

$$x = \frac{l^2(A - A')}{12 \times 27S} \qquad (365)$$

If we replace *S* by its approximate value, $\frac{l(A + A')}{2 \times 27}$, which will produce no important error in this case, we have

$$x = \frac{l}{6} \cdot \frac{A - A'}{A + A'} \qquad (366)$$

in which *A* should always represent the more remote end area from the starting point *A*, Fig. 138. Hence, *x* may be + or −, and it must be applied, with its proper sign, to the distance of the mid-section from the starting point *A*, before multiplying by the contents *S*. Each partial product is thus obtained.

If instead of the areas, A and A', the solidities, S and S', have been taken out for uniform lengths, we may substitute S and S' for A and A' in eq. (366) to find the value of x.

By a similar process with respect to the prismoids composing the mass BD, and using the point B as the starting point, we obtain finally a sum of the products representing this portion of the haul.

If a cut is divided, and parts are carried in opposite directions, the calculation of each part terminates at the dividing line. If a portion of the material in AC is wasted, it must be deducted, and the haul calculated only on the remainder.

The specified limit is sometimes made as low as 100 feet, sometimes as high as 1000 feet. A limit of about 300 feet, however, is usually most convenient, as it includes the wheelbarrow work, and a large part of the carting, while it protects the contractor on such long hauls as may occur.

290. Quantity Profile. The ordinary railroad profile gives to scale all center line depths and the relative positions of cuts and fills, but does not show the quantities of material in them. The *quantity profile* is so drawn that its several areas above or below the grade line are proportional to the number of cubic yards in the several cuts and fills. To obtain this result we lay off from the grade line at each point where we have a cross-section a vertical ordinate, plus or minus, representing to scale the number of cubic yards in a length of one foot due to that section. Connecting the extremities of the ordinates by a smooth curve we have the quantity profile. Upon this the center of gravity of each cut or fill is not difficult to find graphically; and equal areas, whether in cut or fill, indicate equal solidities. The quantity profile assists in a study of the proper disposition to be made of material in the construction of the road, and in computing the distances that some materials are to be hauled.

The Mass Diagram

291. The Mass Diagram shows by a single vertical ordinate the aggregate number of cubic yards involved up to that point, and its several areas indicate the product of cubic *yards removed* by the distance hauled. It is constructed upon a horizontal zero line laid off into stations with the same scale as the profile. Fig. 139.

Beginning at any assumed point of the road, and having computed the quantity of earthwork required between that point and the next, and the next, etc., we find the *algebraic sum* of these quantities by continuous addition, and lay off the sums so found as vertical ordinates, plus or minus, each at its proper point on the zero line. Joining these ordinates by a smooth flowing line we complete the curve of the mass diagram. The ordinates should be tabulated in a systematic way, as here shown, the quantities of cut and fill being distinguished by separate columns as well as algebraic signs, providing also for side-hill sections. The shrinkage column contains the cubic yards of fill in the preceding column, increased by the estimated percentage required to make good the shrinkage. The last column contains the ordinates for the diagram.

Station.	Center *d*	Cubic Yards.		Shrinkage %	Cu. Yds. Sums.
		Cut.	Fill.		
0	+7.3				
+30	+5.0	155			+155
+90	+3.3	199			+354
1	+2.6	34			+388
+40	0	66			+454
2	−1.8		48	8	+402
3	−2.3		156	8	+233
4	−3.4		220	8	− 5
5	−5.4		382	8	−418

It is evident from the last column that, beginning in a cut, the sums increase to the end of the cut, and then diminish with the following fill. So the diagram shows a *rising line* for every cut to a maximum which is opposite the grade point of the profile; thence a *falling line* indicates a fill, down to its own maximum opposite the next grade point.

Every loop of the diagram is composed of two equal parts, one of cut and the other of fill, and the number of cubic yards in each part is indicated by the length of the maximum ordinate which divides them, reckoned from any horizontal line drawn across the loop. The intersection of this line with the loop indicates the stations between which so much of the cut and its corresponding fill are located.

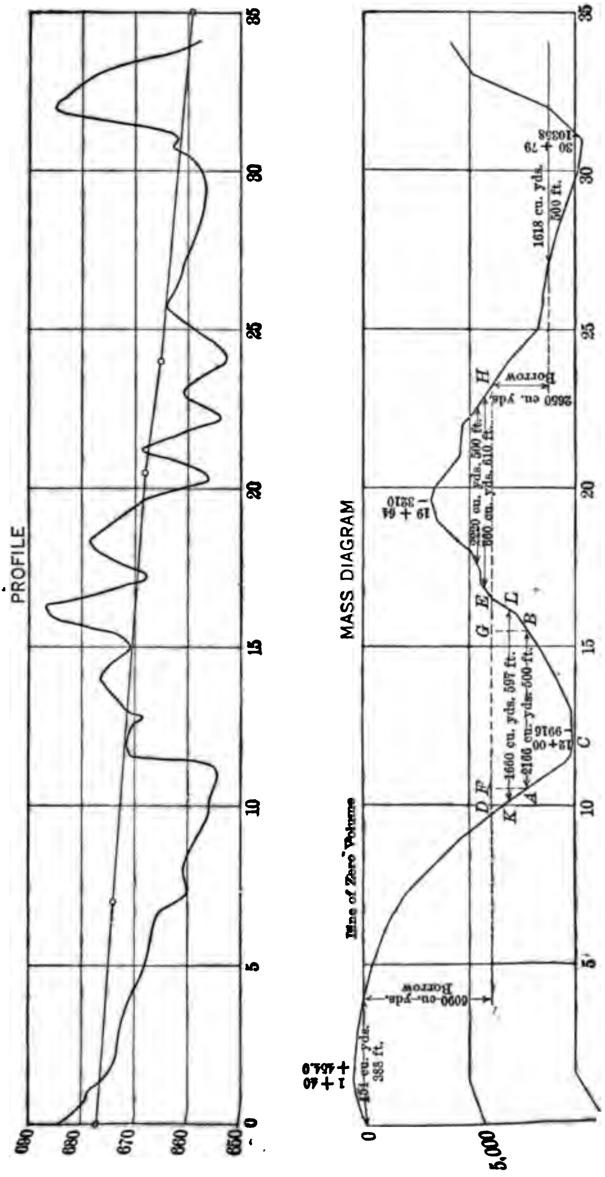
PROFILE
680
680
670
660
650
0
5
10
15
20
25
30
35
MASS DIAGRAM
Line of Zero Volume
0
5,000
1 + 40
+454.0
454 cu. yds.
388 ft.
6090 cu. yds.
Borrow
A
B
C
D
E
F
G
H
K
L
1660 cu. yds. 597 ft.
2166 cu. yds. 500 ft.
12+00
-9916
2220 cu. yds. 500 ft.
560 cu. yds. 610 ft.
19 + 64
-3210
2650 cu. yds.
Borrow
1618 cu. yds.
500 ft.
30 + 79
-10358

Fig. 139.

So the vertical distance intercepted between any two horizontal lines is the measure of the cubic yards of cutting on the rising side, or of fill on the falling side, while the longer line indicates the extreme haul, and the shorter the least haul. Projecting the ends of these lines upon the profile will give the corresponding station points. The average of the horizontal lines in stations, *less* the number of stations of free haul, multiplied by the number of cubic yards moved, gives the product to which the price for "haul" is to be applied.

In the diagram the loops *convex* upward indicate the haul to be in one direction, while the loops *concave* upward indicate the haul to be in the other direction, since the movement is always from cut to fill, that is, from rising line to falling line.

When the grade line is so adjusted that cuts and fills balance, and the distances are within practicable limits, the zero line is the only line of reference needed. But borrowed material, since it appears in the diagram only as fill, depresses the diagram, while waste material, appearing only as cut, has the contrary effect. In such cases new equalizing lines must be drawn, parallel to the zero line and as far below or above it as will give an economical adjustment. Projecting the ends of such lines upon the profile fixes the limits of borrow or waste.

The most economical distribution of material demands that, in making a fill the material should be obtained:

First, from the nearest cut.

Second, from a cut such that the cost of haul shall not exceed the cost of excavation.

Third, from a nearby borrow-pit.

Borrow should not be made at one point and waste at another unless the distance is so great as to make the cost of haul prohibitive, or other conditions, such as an unbridged stream, make this course necessary.

In any case the mass diagram is a valuable aid to a satisfactory solution of the question of distribution, as well as that of haul.

292. It is sometimes more profitable to waste material, *and secure needed* amounts from borrow-pits, than to have *excessive haul.* When, on account of waste of the material from a cut, the embankments have to be built from material taken from borrow-pits, the total cost of excavation is doubled. This may be denoted by $2c$, where c = the cost of excavating 1 cubic yard either on the line or in the borrow-pit.

When 1 cubic yard is hauled beyond the limit of free haul, the total cost is $c + nh$, where h = the cost of haul per cubic yard per 100 feet and n = the length of excess haul in stations.

Disregarding the cost of the land for the borrow-pit, and other considerations, the limit of profitable haul will be when

$$2c = c + nh$$

or

$$n = \frac{c}{h} \qquad (367)$$

293. Payment of Overhaul. The following are the recommendations of the American Railway Engineering Association for all cases where an allowance for overhaul is made.

"No payment shall be made for hauling material when the length of haul does not exceed the limit of free haul, which shall be —— feet.

"The limits of free haul shall be determined by fixing on the profile two points—one on each side of the neutral grade point—one in excavation and the other in embankment, such that the distance between them shall equal the specified free-haul limit and the included quantities of excavation and embankment balance. All the haul on material beyond this free-haul limit shall be estimated and paid for on the basis of the following method of computation, viz.:

"All material within this limit of free-haul shall be eliminated from further consideration.

"The distance between the center of gravity of the remaining mass of excavation and center of gravity of the resulting embankment, less the limit of free haul as above described, shall be the length of overhaul; and the compensation to be rendered therefor shall be determined by multiplying the yardage in the remaining mass, as above described, by the length of the overhaul. Payment for the same shall be by units of 1 cubic yard hauled one hundred (100) feet

"Where material is obtained from borrow-pits along the embankment and runways are constructed, the haul shall be determined by the distance the team necessarily travels. The overhaul material thus hauled shall be determined by multiplying the yardage so hauled by one half the round distance made by the team less the free-haul distance. The runways shall be established by the engineer."

Referring to Fig. 139, this recommendation may be easily explained. The length AB is the free-haul limit. The total free haul is represented by the area ACB. The excavation in the area BEG is placed in the embankment in the area ADF. The number of cubic yards on which overhaul is paid is represented by the ordinate BG, and the total distance hauled is given by the line LK. The distance for free haul is subtracted from the length of LK, to give the overhaul distance. *The line LK is drawn through the middle point of BG. The centers of gravity of the two portions BEG and ADF are considered as at the points L and K.*

294. Example. The profile and diagram given in Fig. 139 are taken from an actual line of road. The reasons underlying the method of distribution have previously been given in § 291. 6090 cubic yards of excavation are borrowed between stations 4− and 9+. The two lines DE and EH are "equalizing lines" and give the *minimum total areas* for both the hill and the valley. These lines are equal in length.

Only a portion of the complete problem is shown in the figure and this accounts for the borrowed material near the right. Other lines of equal length occur beyond the limit shown, and it would be unprofitable to haul all material forward as far as it would have to be moved.

The sum of the volumes between successive maximum and minimum points should check with the differences of ordinates of these governing points.

CHAPTER XVI

CONSTRUCTION

295. The engineering department of a railway company is usually reorganized for the construction of the road, as follows: Chief engineer, Division engineers, Resident engineers, Assistant engineers. On some roads the division engineers are styled "Principal Assistants"; the resident engineers, "Assistants"; and the assistant engineers are designated according to their duties, as "leveler," "rodman," etc.

A resident engineer has charge of a few miles of line, limited to so much as he can personally superintend and direct. He has one or more assistants and an axman in his party. All instrumental work is done and all measurements taken by the resident engineer and his assistants.

A division engineer has charge of several residencies, and inspects the progress of the work on his division once or twice a week. In his office, which should be centrally located, all maps, profiles, plans, and most of the working drawings required on his division are prepared. To him the resident engineers make detailed reports once a month, or oftener if necessary, which he passes upon as to their correctness, and from which he makes up a monthly report, or estimate, of the amount and value of the work done and materials provided by each contractor on his division. The estimates are forwarded about the first of each month to the chief engineer, who examines and approves them, returning for modification any that seem to require it.

The chief engineer has charge of the entire work, and directs the general business of the engineering department. He occasionally inspects the work along the line.

296. Clearing and Grubbing. The first step in the work of construction is to clear off all growth of timber within the limits of the right of way. The resident engineer with his party passes over the line, making offsets to the right and left, and blazing the trees which stand on, or just within, the limits of the company's property. The blazed spot is marked with a letter *C*, as a guide to the contractor. After felling, the valuable timber should be piled near the boundary lines, to be saved as the property of the company. The brushwood is burned.

Where a deep cut is to be made, the stumps are left to be removed as the earth is excavated. In very shallow cuts and fills the contractor will generally prefer to tear up the trees by their roots at once, rather than to grub out the stumps after clearing. Where the embankments will be over 3 feet high, grubbing is not necessary; but the trees require to be *low-chopped*, leaving no stump above the roots. The engineer should indicate to the contractor the localities where each process is suitable.

297. While the clearing is in progress, the engineer should run a line of test levels touching on all the benches to verify their elevations; he may also rerun the center line, replacing any stakes that may have disappeared, and setting guard plugs to any important transit points which may not have been previously guarded. If any changes in the alinement have been ordered, these may be made at the same time.

298. Cross-sections. The resident engineer is furnished with a profile of the portion of the line in his charge, upon which is plainly indicated by line and figures the established grade. The grade given on the profile is that which is subsequently called the subgrade, being the surface of the roadbed. The final or true grade is the upper surface of the ties after the track is laid.

The methods used in cross-sectioning are fully described in Chapter XI.

The cross-section notes should be traced in ink at the first opportunity to secure their permanence. An office copy should also be made to serve in case of loss or damage to the original.

299. Shrinkage. In estimating the relative amounts of excavation and embankment required, allowance must be made for difference in the spaces occupied by the material before excavation and after it is settled in embankment. various earths will be more compact in embankment, rock *less* so. The difference in volume is called *shrinkage* in the one case, and *increase* in the other.

The amount of shrinkage depends on the kind of material and the method of placing it in the fill. Dumped from a trestle, earth falls so loosely at first that the shrinkage is apparently greater than when the fill is made in layers hauled on by wagon or scraper. A trestle fill requires several months to settle, and it is well to give it a little additional height to provide for the inevitable settlement. The slope stakes, however, are set for the true grade. The surplus height, if given at all, is made in the trestle, or is shown by poles or stakes driven at $\frac{1}{2}b$ from the center line as the fill nears completion.

But the probable shrinkage must be considered also when the grade is first established in order to provide sufficient material from the cuts, if possible, to complete the fills. When the material is paid for as measured in excavation, the quantity to be placed in the fills is computed only for the purpose of properly balancing the work.

Excess of earth allowed for shrinkage is estimated as a percentage of the quantity computed from the cross-section notes; the excess of height required to provide for shrinkage is estimated as a percentage of the height of fill. These two are not necessarily the same.

The percentages here given are from the average of general experience. They express shrinkage in volume of the several classes of materials.

Fine Sand	6%	Loam	12%
Sand and Gravel	8	Surface Soil	15
Ordinary Clay	10		

When a fill is carried up under traffic, the subsequent shrinkage will be less than half the above.

The percentage in height depends on the height as well as on the material. If P is the above tabular per cent of bulk, and p the corresponding per cent of height, then p takes the following values:

d	p	d	p
5 feet	$.75P$	30 feet	$.56P$
10 feet	$.67P$	40 feet	$.54P$
20 feet	$.60P$	50 feet	$.52P$

No slippery earth or quicksand should be allowed in any fill.

Rock blasted in large fragments increases its bulk about 60 per cent; in smaller fragments it increases about 75 per cent.

Embankments should be started at full width out to the slope stakes, and finished at full width of the roadbed even when at a percentage above grade, as there will be both lateral and vertical shrinkage.

Example. A fill of level section, 30 feet high, is built of ordinary clay. Cubic yards per station, 6556; 10 per cent extra for shrinkage, 656 cubic yards. Extra height if dumped from top, 30 × .10 × .56 = 1.68 feet. Such estimates are necessarily approximate, being subject to the state of the weather, time of year and peculiarities of the soil. Frozen embankments settle excessively when thawed out.

300. Alteration of Line. Inasmuch as the center line at grade is the base of reference for all measurements and calculations in earthwork, any change made in it after the work of grading has begun should be most carefully recorded and explained. The center stakes of the old line should be left standing until after the new line is established, so that the perpendicular offset from the old line to the new, at each station, may be measured, as also the distance that the new station may be in advance of, or behind the old one. The *date* of the change should be recorded. The original cross-sections are extended any amount requisite, the distance out being still reckoned from the *old* center, while a marginal note states the amount by which the center has been shifted.

The difference in length of the lines will make a long or short station at the point of closing. The exact length of such a station should be recorded, so that it may be observed in retracing the line at any time, and in calculating the quantity of earthwork. The original transit notes of the altered line should be preserved, but marked as "abandoned," with a reference to the notes of the new line on another page.

301. Drains and Culverts. The engineer should examine the nature and extent of each depression in the *profile with* reference to the kind of opening required for the *[illegible]age of water*. For small springs, and for a limited sur-[illegible] *of rainfall*, pipes, in sizes varying from 12 to 24 inches diameter, serve an excellent purpose as drains. These are easily laid down, and if properly bedded, with the earth tamped about them, are very permanent; but their upper surface should be at least 2½ feet below grade. The embankment is protected at the upper end of the drain by a bit of vertical wall, enclosing the end of the pipe. If necessary, a paved gutter may lead to it.

Where stone abounds, the bed of a dry ravine may be partly filled with loose stone, extending beyond the slopes a few feet, which will prevent the accumulation of water.

When the flow of water is estimated to be too great for two lines of the largest pipe, a culvert is required. A pavement is laid 1 foot thick, protected by a curb of stone or wood 3 feet deep at each end, and wide enough to allow the walls to be built upon it. It should have a uniform slope, usually between the limits of 50 to 1 and 100 to 1 to ensure the ready flow of water. In firm soils the foundation pit is excavated 1 foot below the bed of the stream, but if mud is found this must be removed and the space filled with riprap, the upper course of which is arranged to form the pavement at the proper level. In a V-shaped ravine, requiring too much excavation at the sides, and where the fall is considerable, riprap may be used to advantage, the bed of the stream above the culvert being graded up by the same material to meet the pavement. In some cases a curtain, or cross-wall, is necessary on the lower end to retain the riprap.

Culverts should be laid out at right angles to the center line whenever practicable, the bed of the stream being altered if necessary. The length of an open culvert is the entire distance between slope stakes, the walls being parallel throughout, or the length may be taken somewhat less than this, and the walls turned at right angles on the upper end, forming a facing to the foot of the slope. The walls are carried up to grade for the width of the roadbed, and are stepped down to suit the slopes. A course is afterwards added to retain the ballast.

In box culverts the span varies from 2 to 5 feet, the height in the clear from 2 to 6 feet; the thickness of walls from 3 to 4 feet; the thickness of cover from 12 to 18 inches, and *its length at least* 2 feet greater than the span.

walls terminate in short head-walls built parallel to the center line, the top course being a continuation of the cover. The length of a head-wall, measured on the outer face, is equal to the height of the culvert in the clear multiplied by the slope ratio of the embankment. The perpendicular distance from the center line to the face of a head-wall is equal to one half the roadbed, *plus* the depth of the top of the wall below grade multiplied by the slope ratio, or $\frac{1}{2}b + sk$. A coping is sometimes added.

302. Arch culverts are used when the span required is more than 5 feet, and the embankment too high to warrant carrying the walls up to grade as an open culvert. The span varies from 6 to 20 feet; the thickness of arch from 12 inches to 18 or 20 inches. The height of abutments to the springing line varies from 2 to 10 feet, the thickness at the springing line from 3 to 5 feet, and at the base from 3 to 6 feet. The foundations are laid broader and deeper than in box culverts, each abutment having its own pit, carried to any depth found necessary. The half length of the culvert is $\frac{1}{2}b + sk$, in which k is the depth of the crown of the arch below grade. The abutments are carried up half way from the spring to the level of the crown of the arch, and thence sloped off toward the crown. The face walls are carried up to the crown, and coped. The wing walls stand at an angle of 30° with the axis of the culvert; they receive a batter on the face, and are stepped (or sloped) down to suit the embankment. Their thickness, at the base, is the same as that of the abutment; at the outer end 3 feet. They stop about 3 feet short of the foot of the slope. They need not be curved in plan.

Any stone structure of dimensions greater than those given above, scarcely comes under the head of culverts, and should be made the subject of a special design by the engineer.

303. Staking out Foundation Pits. For Box Culverts. The engineer having decided upon the size of culvert required, makes a diagram of it in plan, on a page of his masonry book, recording all the dimensions stating the station and *plus* at which its center is taken, the span and height of the opening, etc. He then sets the transit at the center A, Fig. 140, measures the angle between the center line and axis (making it 90° if practicable); on the axis he lays off the distances to the ends of the culvert and drives stakes at *B* and *C*. Perpendicular to *BC* he lays off the half widths of the pit, setting stakes at *D* and *E*, and laying off *DF* and *EH* = *AB*; and *DG* and *EI* = *AC*. On *IG* produced he lays off *CJ* = *CK*, and perpendicular to this *JM* and *KL*, and finds the intersections *O* and *N*. A stake is driven at each angle, and upon it is marked the cut required to reach the assumed level for the foundation. These cuts are recorded on the corresponding angles of the

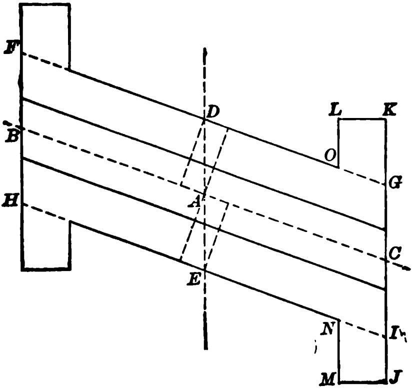

FIG. 140.

diagram. The pit is thus no larger than the plan of the proposed masonry, and the sides are vertical, which answers the purpose for shallow pits.

For Arch Culverts. The pit for each abutment when shallow may be of the same dimensions as the lower foundation course; if more than 5 feet deep, it should be enlarged by an extra space of 1 foot all around. In Fig. 141 the inside lines show the plan of the abutments at the neat lines; the outside lines represent the pits. Having prepared a plan of the structure suited to the locality, and made a diagram of the same in the masonry book, set the transit at *A*, and drive stakes at *D*, *E*, *N* and *O* on the center line. Then turning to the axis BC, lay off AC, and set stakes at G and I. With G as a center and a radius equal to $2DE$, describe on the ground an arc cutting EI in X or ($IX = DE \cdot \cot 30°$) may be calculated; and on XG produced lay off GK, and perpendicular to this, KL. From N lay off NP, parallel to AC, and measure PL as a check. Drive a stake at each angle, marked with the proper cutting, and record the same on the diagram. The locality may require the wings to be of different lengths and angles, of which the engineer will judge. Guard-plugs should be driven in line with the intended face of one or both abutments, so that the neat-lines can be readily given when

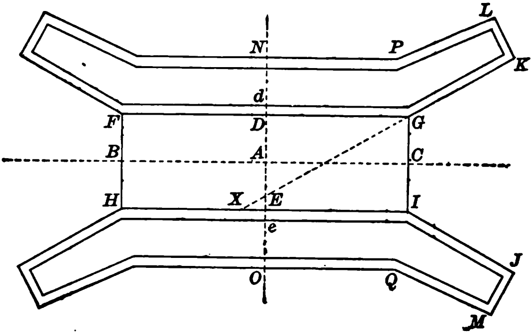

FIG. 141.

required. In case the material is not likely to stand vertically, the pit must be staked out with sloping sides, as described below.

For Bridge Abutments. A design for every important structure is usually prepared in the office after a survey of the site. The foundation pit is then laid out from dimensions furnished on a tracing, but a diagram of the pit should be made in the masonry book as usual. *When the bridge is on a tangent*, Fig. 142, set the transit at A on the center line at its intersection with the axis BC of the abutment *at the level of the seat*. Deflect from the tangent the angle giving the direction of BC, and lay off AC, AB, setting plugs at B and C, and reference plugs (two on each side) BC produced. After staking out the sides of the pit parallel to *BC*, set the transit at *C*, and deflect the angle for the wing, laying off *CD*, and driving stakes at the corners *E* and *F*. Two reference points are then set on the line *CD* produced. The other wing being staked out in the same manner, the cut is found at each stake and marked and recorded. Cross-sections are then taken near each corner, perpendicular to each side, and slope stakes (marked "slope") are driven where the slope runs out. Intermediate sections are taken when the unevenness of the ground makes it necessary, and the lines joining the slope stakes are produced to intersect, and other stakes are driven at the intersections. The position of each stake is shown on the diagram, and the cut recorded.

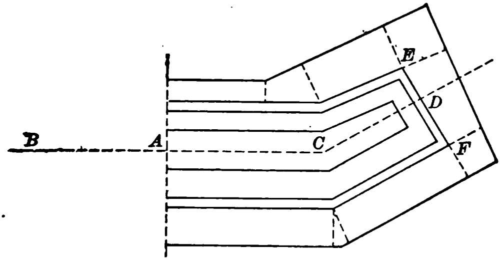

Fig. 142.

A slope of 1 to 1 is usually sufficient for pits. If the material will not stand at 1½ to 1, or if space cannot be spared for the slope, the sides may be carried down vertically, supported by sheet piling braced from within.

The reference points should be so chosen that the points *A*, *B* and *C* may be found by intersection, on any course of the masonry, during the progress of construction.

When the bridge is on a curve, the bridge-chord should be found and the abutments laid out from this. Fig. 143. The bridge-chord is a line *AB*, midway between the chord of the curve *CD*, joining the centers of the abutments, and a tangent to the curve at the middle point of the span. Hence $CA = DB = \frac{1}{2}MN$, which may be laid off, and *A* and *B* are the true centers of the abutments, from which the foundations are staked out as before.

The distance $CE = DF$ to the points where the brid chord cuts the curve is $0.147CD$.

Should an abutment site on a curve be inaccessible, when under water, from any transit point P on the cur lay off PX perpendicular to the tangent at M, observ that

$$PX = MQ - AC = R\ (vers\ PM - \tfrac{1}{2}\ vers\ CM)$$

and

$$AX = PQ - \tfrac{1}{2}AB = R\ (sin\ PM - \tfrac{1}{2}CD)$$

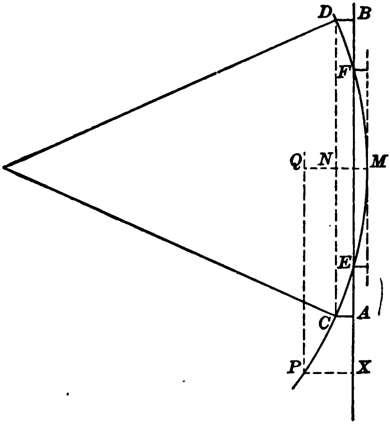

FIG. 143.

The point A may then be found by intersection, or direct measurement with a steel tape or wire, driving a l stout stake to show the point above the water. Ot points may then be approximately found, sufficient begin operations.

In case of a bridge of several spans, the piers are laid in the same manner, from a center point and axis. If o curve, each span has its own bridge-chord, but for conv ience, the center of a pier may be taken on the center during its construction, and the bridge-chord only fo for the purpose of placing the bridge; the piers being l enough to allow of the shift.

To locate the centers of piers, a base line is requi on one or both shores, and two transits are used to give the intersections by calculated angles. When practicable the spans should also be measured with a steel tape or wire.

The bed of a pit for any sort of structure should receive the closest scrutiny of the engineer, it being his duty to judge whether the material will resist the load to be imposed upon it. A pit may require to be excavated to a greater depth than first ordered, while sometimes a less depth will answer, as when solid rock is found. When a good material is reached, if any doubt exist as to its thickness, or as to the character of the underlying stratum, borings should be made or sounding rods driven down. Piles may be driven to gain the requisite firmness, and a layer of riprap, concrete, or of timber may be used. to afford a uniform bearing. When satisfied of the stability of the bed, the engineer finds the the original centers, and gives points for the courses of masonry. A complete record is kept of the amount and kind of excavation, the materials used in foundation under the masonry, and of the size and thickness of each foundation course of masonry; the notes should be taken at the time the work is done, it being generally impossible to take measurements thereafter.

304. Cattle-guards are located at highway grade crossings. They are placed at right angles across the road at the fence lines to prevent the passage of live stock. The surface guard is the form used most extensively at the present time. The material is either wood or metal.

305. Trestle Work. No wooden culverts should ever be used. If stone cannot be had at first, two trestle bents may be erected, leaving between them a space sufficient to contain the stone structure to be built when the material for it can be brought by rail. The bents may be backed by plank to retain the embankment, and the stringers are then notched down an inch on the caps to receive the pressure of the earth, and render the bents mutually sustaining. The sills are prevented from yielding to the pressure of the earth by being sunk in a trench, or by sheet piling. Should the span be too long, a central bent may be used, so as not to interfere with building the wall. Sometimes pile-bents may be used with greater advantage, the piles being driven *in rows of four* each, and capped to receive stringers. In districts where suitable stone is entirely wanting, pile or trestle abutments and piers are used for the support of bridges, the piles or posts being arranged in groups and capped to receive the direct weight of the trusses. They should not sustain the embankment, but should be connected with it by a short trestle work.

Trestle work is frequently used as a substitute for embankment, either to lessen the first cost, or to hasten the completion of the line, or for lack of suitable material with which to form an embankment. The cost of trestle work, however, is not less than that of an earth embankment formed from borrow-pits, unless its height exceeds about 15 feet, depending on the relative prices of materials and labor. When not exceeding 30 feet in height, the *bents*, for single track, are usually composed of two posts, a cap and sill, each 12 × 12, and two batter posts, 10 × 12, inclined at ¼ to 1, all framed together. Two lengths of 3-inch plank are spiked on diagonally on opposite sides of the bent as braces. The length of the caps should equal the width of the embankment; the posts should be 5 feet from center to center, and the batter posts 2 feet from the posts at the cap. The sill should extend about 2 feet beyond the foot of the batter post. A masonry foundation for the bent is preferable, though pile foundations are not uncommon, and some temporary structures are placed directly on a firm soil, supported only by mudsills laid crosswise under the sill. The spans, or distance between bents, may vary from 12 to 16 feet. The stringers should consist of at least four pieces, two under each rail, bolted together, with packing blocks to separate them 2 or 3 inches. Over each bent and at the center of each span a piece of thick plank about 4 feet long should be placed on edge between the two pair of beams to preserve the proper distance between them, while rods pass through the beams and strain them up to the ends of the plank, to increase the stability of the beams and prevent their buckling under a load. The stringers should be able to carry safely the heaviest load without bracing against the posts. The bents, however, if high, [illegible]*ust* be braced against each other. The stringers should [illegible] *continuous,* the two pieces breaking joints with each [illegible]*r at the* bents, to which they are firmly bolted. They may rest directly on the caps, or corbels may intervene. The spans on a curve should be shorter than on a tangent. The ties should be notched down to fit the stringers closely, and guard rails, either wood or iron, secured to them firmly. Unless the spans are very short, horizontal bracing should be employed, consisting of 3-inch plank, extending from the center of each span to the ends of the caps, which are notched down to receive the plank.

For trestles much higher than 30 feet **the cluster bent** is preferable, so termed because each vertical post is composed of a cluster of four pieces, 8 × 8, standing a little apart to allow the horizontal members to pass between them. The verticals are continuous, breaking joints, two and two, while the horizontals pass the posts and are bolted to them at the joints; the framing is accomplished entirely by packing blocks and bolts. The batter posts consist each of two pieces 8 × 8; the horizontals may be 4 × 10, and extend not only across the bent, but from one bent to another. Proper bracing is also used in every direction. When very high, a secondary pair of batter posts may be introduced in the lower part of the structure. The batter need not exceed ⅙th to 1. In some instances two adjoining bents are strongly braced together, forming a tower or pier, and the piers placed from 50 to 100 feet apart, the roadway being carried on trussed bridges. The cluster bent admits of any piece being removed and a new one inserted when necessary.

Iron trestles are now adopted where a permanent structure is desired. Owing to the expansion of the metal by heat, the bents cannot be continuously connected with each other as in a wooden trestle; hence the pier form is resorted to, having spans varying from 30 to 150 feet, covered by trussed bridges, and the whole structure is more properly styled a viaduct.

306. Tunnels. Tunnels are adopted in certain cases to avoid excessive excavations, steep grades, high summits, and circuitous routes. Their disadvantages are the increased time and cost of their construction compared with an open line, and their lack of light and fresh air when in use. It is desirable that they should be on a tangent throughout, both for the admission of light and for convenience alinement. Many tunnels, however, have been built with a curve at one or both ends or curved throughout.*

The location of a tunnel, other things being equal, should be such as to make not only the tunnel proper, but also its immediate approaches by open cut as short as possible; and the latter should be selected so as not to be subject to overflow, nor liable to landslides. The material to be encountered may frequently be determined with tolerable accuracy by a study of the geological formation in the vicinity, or by actual borings. The most favorable material for tunneling is a homogeneous self-supporting rock, devoid of springs, which does not disintegrate on exposure to the atmosphere. The worst materials are saturated earth and quicksand. The presence of water in any material increases the cost considerably.

The alinement of a tunnel is made the subject of special survey, after the general location is decided, and this is more or less elaborate according to the length of tunnel. A permanent station is established at the highest point crossed by the tunnel tangent, from which, if possible, monuments are set in each direction at points beyond the ends of the tunnel. If there are two principal summits, stations on these will define the tangent, which may then be produced. The monuments established beyond the tunnel should be sufficiently distant to afford a perfect backsight from the ends of the tunnel, where other monuments are also established. The first quality of instruments only should be used, and these perfectly adjusted, and the observations should be repeated many times until it is certain that all perceptible errors are eliminated. Since the line of collimation will be frequently inclined to the horizon at a considerable angle, it is important that it should revolve in a vertical plane; and to secure this, a sensitive bubble tube should be attached to the horizontal axis, at right angles to the telescope of the transit. The distance may be obtained by triangulation, though direct measurement is to be preferred. A steel tape is convenient and accurate, providing that allowance be made for variations due to temperature, from an assumed standard. The rods described in § 43 may be used instead of plumb lines, the tape being held at right angles to them, and therefore horizontal. A plug should be driven for each rod to stand on, and a center set to indicate the line and measurement.

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* *The Mont Cenis* tunnel, requiring a curve at each end, was first *opened on the tangent* produced, giving a straight line through, and *the curves were excavated* subsequently.

As the excavation of the tunnel proceeds, the center line is given at short intervals by points either on the floor or roof. Overhead points are generally preferred, from which short plumb lines may be hung, constantly indicating the line, with little danger of being disturbed. When a new transit point is required in the tunnel, it should be established directly under an overhead point, which serves as a check upon its permanence, and as a backsight when needed.

Shafts are sometimes opened to give access to several points of the tunnel at the same time, thus facilitating the work, though at an increased cost. They also serve for ventilation during the progress of the work, though they are worse than useless for this purpose afterward, except possibly in the case of a single shaft near the center of the tunnel. Some of the longest tunnels have been formed without shafts, while many shorter ones have had several, which have generally been closed after the tunnel was completed. Shafts are either vertical, inclined, or nearly horizontal; in the latter case they are called adits. Inclined shafts should make an angle of at least 60° with the vertical. Vertical shafts may be either rectangular, round, or oval. Their dimensions vary, depending on their depth and the material encountered, between 8 and 25 feet. They are usually sunk on the center line of the tunnel, though sometimes at one side. When over the tunnel the alinement below is obtained directly from two plumb lines of fine wire suspended on opposite sides of the shaft from points very carefully determined at the surface. The plummets are suspended in water to lessen their vibrations, and as soon as the transit can be set up at a sufficient distance to bring the lines into focus, it is shifted by trial into exact line with the mean of their oscillations, the latter being very limited. Permanent points may then be set, but should be repeatedly verified. As soon as the workings from a shaft communicate with those from either end, or from another shaft, the alinement thus found is tested, and revised if necess

These operations require the greatest nicety of observation and delicacy of manipulation to obtain satisfactory results.

From plumb lines in the central shaft of the Hoosac tunnel, the line was produced three tenths of a mile, and met the line produced 2.1 miles from the west end with an error in offset of five sixteenths of an inch. In the Mont Cenis tunnel the lines met from opposite ends with "no appreciable" error in alinement, while the error in measurement was about 45 feet in a total length of 7.6 miles.

When **a curve** occurs in a tunnel it is usually near one end. The tunnel tangent is produced and established as before described, and a second tangent from some point on the curve outside the tunnel is produced to intersect it, the intersection being precisely determined and the angle measured with many repetitions. The tangent distances are then calculated, and the position of the tangent points corrected by precise measurements, and permanent monuments are established. As the tunnel advances, points may be set at short intervals on the curve in the usual manner; but at intervals of 100 feet the regular stations should be defined with finely centered monuments, using a 100-foot steel tape carefully supported in a horizontal position. When it is necessary to use a subchord, its exact length should be calculated as shown in § 107. When the curve has advanced so far as to render a new transit point necessary, this should be established at a full station. The subtangents from the two transit points should then be produced to intersect, and measured for equality with each other and with their calculated length. The distance from their intersection to the middle of the long chord should also be measured as a check on the deflections. When no perceptible errors remain, the curve may be produced as before until the P.T. is reached. It is evident that correct measure is indispensable to correct alinement on curves. Should obstacles on the surface necessitate triangulation, more than ordinary care must be exercised, and as many checks introduced as possible. The triangles should be so arranged that all of the angles and most of the sides may be measured.

Test levels are carried over the surface with great care, [illegible]ch *turning* point being made a permanent bench, and [illegible]*levation* determined with a probable error not exceeding

0.005 foot. Levels may be carried down a shaft on a series of bolts or spikes about 12 feet apart in the same vertical line, the distances being measured by the same level-rod as that with which the benches are determined. The measures should be taken between two graduations of the rod, not using the end of the rod, which may be slightly worn. Fine horizontal lines on the heads of the bolts may be used to mark the exact distances. After the shaft reaches the level of the tunnel, the depth may be measured more directly with a steel tape, the entire length of which has been corrected at the given temperature, by comparison with the same rod.

If the **grade of a tunnel** is to be continuous, it should be assumed at something less than the maximum of the road, but not less than 0.10 per station, which is required for drainage. If a summit is to be made in the tunnel, the grade from the upper end should not exceed 0.10 per station. Grades are given in the tunnel from day to day, or as often as required by the progress of the work, the marks being made on the sides at some arbitrary distance above grade. Turning points should be taken on permanent benches.

The least width of a tunnel in the clear should be, for single track about 16 feet, and for double track this distance should be increased by the distance between tracks. **The height** in the clear above the tie should be 22.5 feet for both single and double track, allowing for tie and ballast, this distance being measured at the center lines of each track. **The form** of section depends somewhat on the material traversed. In perfectly solid rock a nearly rectangular section may be used, the roof being slightly rounded. In dry clay, and stratified rock, a flat arch may be used, and in other cases a full-centered arch. The latter form is rather to be preferred on account of the better ventilation afforded. The sides are made vertical, battered or curved, as necessity or taste may dictate. In wet and infirm soil an invert floor may be required, otherwise it is made level transversely. When a lining is required the original section must of course be made large enough to allow for the masonry, and the temporary timber supports behind it. Hard-burned brick is usually adopted for arching, being durable and easily handled. In loose rock the arching may be from 13 to 2[illegible] inches thick, in wet and yielding soil a thickness of from 26 to 39 inches may be necessary. The walls may be from 2½ to 6 feet thick.

In forming a tunnel, **a heading** or gallery of smaller cross-section is first driven and afterward enlarged to the full size required. In firm clay or loose rock which will temporarily support itself until the masonry can be put in, it is better to drive the heading along the floor (at subgrade) of the tunnel, the remaining material being then easily thrown down in sections as the arching is advanced. In solid rock, or wet earth, a top-heading (along the roof) is generally preferred. The dimensions of a heading driven by hand are usually 8 feet high by 8 or 10 feet wide, but in solid rock where drilling machinery is introduced, it is advantageous to make the heading as wide as the tunnel at once. By drilling holes into the face at points about 5 feet each side of the center, and converging on the center line at a depth of about 10 feet, a triangular mass of rock may be blown out, and the space thus gained facilitates the blasting of the adjacent rock on either side. An advance of about 10 feet in each day of 24 working hours may thus be made, using nitroglycerine in some form as the explosive agent. Owing, however, to unavoidable delays from various causes, this rate or progress cannot always be maintained. At the Hoosac tunnel the greatest advance in one week was 50 feet; in one month 184 feet at one heading. At the Musconetcong tunnel a heading 8 × 22 feet in syneitic gneiss was advanced at the average rate of 137 feet per month for six months, the maximum being 144 feet—the enlargement of the tunnel to full size going on at the same time, a few hundred feet behind. At the St. Gothard tunnel the north heading 2.5 × 3 meters was advanced in mica gneiss, during the year 1875 at the average daily rate of 3.71 meters, with a maximum of about 4 meters, but the enlargement was not made. The south heading advanced at the rate of 2 meters a day, timbering being at times necessary.

In ordinary clay a heading may be driven at from 75 to 180 feet per month, according to circumstances, where *timbering* is put in. The enlargement, including timbering [illegible] *masonry*, may be advanced at from 20 to 60 feet per [illegible]*th.* Small tunnels for water conduits are driven through dry clay at the rate of 10 feet per day, the masonry following at once without timbering.

The compressed air used to drive the drilling machinery serves to supply ventilation also. When this is wanting or proves insufficient, exhaust fans are used. At Mont Cenis a horizontal *brattice* or partition was built in the tunnel, dividing it so as to secure a circulation of air. When foul gases are encountered, ventilation becomes a serious question, and in one instance an important work was abandoned for this cause.

Cross-sections of the heading, and also of the tunnel enlargement, should be measured at intervals of about 20 feet, as soon as opened, to see that the sides, roof, and floor are taken out to the prescribed lines, at the same time that the latter are exceeded as little as possible. In solid rock, since some material outside of the true section will necessarily be thrown down, leaving an irregular outline, it is well to take two cross-sections at the same point, one following the projections and the other the recesses of the rock, from which an average section may be estimated. A daily, or at least a weekly, record of operations should be kept in tabular form, and the progress indicated by a profile and cross-sections drawn on a sufficiently large scale to show details.

The drainage of a tunnel is best secured by a line of stoneware or cement pipe laid in a trench along each side, and covered with ballast or other loose material. The entire floor is thus made available for the use of the trackmen. When an invert is used, the drain is placed in the center between tracks. If the amount of water is large, drain pipe may be laid behind the walls, and the back of the arch may be covered with asphaltum, or coal tar, to prevent a constant dripping on the track.

307. Retracing the Line. As the grading progresses, in either excavation or embankment, the principal transit points are established on the roadbed from the points of reference, and the center line is retraced, setting stakes at every 50 feet. Transit points on grade should be fixed upon stout, durable posts firmly set in the ground, and standing high enough to be easily reached after the ballast is laid. To *recover the old line,* any discrepancies in measureme must be left between the transit points where they occur, and not carried forward. In retracing a curve, if the transit is placed at the forward point, allowing the chain to advance *toward* it, slight differences in measurement will not affect the position of the curve. If any short or long stations have been introduced on the location, their position on the line must not be changed in retracing. The chain may be adjusted so that its measures will agree with the recorded distances between transit points. Offsets are made right and left from the new stakes to see that the roadbed is of the full width at all points. The levels are also carried over the grade, and any remaining cut or fill found necessary is marked on the back of the stakes, due to allowance being made for the probable settlement of embankments.

308. As the work approaches completion the contractor goes over the line, dressing it to grade and opening the side ditches if this has not been previously done.

Drain-tile should be laid at the bottom of these ditches and lightly covered with earth, particularly if the cut be wet. These not only prevent the water from reaching the ballast, but by keeping the foot of the slope comparatively dry prevent the earth from sliding down and filling up the cut. There is also a marked economy in their use, as the cost is trifling, and all further excavation of mud and water from the cut is generally obviated. Should any springs appear in the slope a branch line of smaller tile may be laid to meet it. If the slope is liable to be overflowed from the surface above, an open ditch should be dug a few feet beyond the slope stakes, leading the surface water to discharge elsewhere.

309. The final estimate is a complete statement in detail, of the amount of work done and materials provided, in the construction of the road, and is the basis of final settlement between the company and contractor. Its preparation should be begun as soon as possible after the work is in progress, and should be continued, as fast as the necessary data are accumulated, while the circumstances are still fresh in mind, and when any omissions in the field notes may be readily supplied. The content of each prismoid, the classification of its material, and the length of haul which it is subject, should be matters of special record a book provided for that purpose. These results having een carefully computed by exact methods, form a standard f comparison for those approximate results which must e had from time to time during the progress of the work, nd furnish a limit to the amounts of the monthly estimates. he same remark applies to all other items of labor and aterial. The notes and record of the final estimate should e particularly full and exact in respect to all such items as ill be inaccessible to measurement at the completion of he work, such as foundation pits, foundation courses of asonry, culverts, and works under water.

310. Monthly Estimates. On or before the last day f every month during the progress of construction, measureents are taken to determine the total amount of work done nd material provided up to that date. The estimates ased on these measurements are called Monthly Estimates. t is frequently necessary to take measurements for both onthly and final estimates at other times than the end f the month, as in the case of foundations which are not ong accessible. With respect to each piece of work satisactorily completed, the monthly estimate should be exact, nd identical in amount with the final estimate. With espect, however, to items of work in progress at the time f measurement, the monthly estimate is only approximate, et should be as precise as the nature of the case will allow; nd the quantities stated should not be in excess of fair roportion of the total quantities given on the final estimate or the same piece of work.

A special field book is devoted to monthly estimate otes. Each page should be dated with the day on which he notes upon it were taken. The notes consist of measureents of all sorts, principally of cross-sections partially xcavated. These sections should be at the same points n the line as the original sections, so that comparisons ay be made. Wherever the excavation is finished to rade, it is only necessary to write "completed" opposite uch stations, and the quantities may be taken from the final estimate or computed from the original notes. It is frequently necessary to retrace portions of the center line in taking estimate notes, so that all the field instruments are required, *but a party* of three or four men is usually sufficient.

If the contractor has provided materials, such as stone, lumber, etc., which are not as yet put into any structure when the estimate is taken, these should be measured and entered under the head of **temporary allowance,** an arbitrary price being used somewhat below the actual value of the material as delivered. Such allowances should never be copied from one month's estimate to the next, but made anew on such material as may be found that seems to require it. But all *completed* items of contract work, and of extra work when ordered by the engineer, are necessarily copied from one monthly estimate to the next during the continuance of the contract.

A blank form is used by the resident engineer in reporting monthly estimates, on which a column is provided for each class of material and work required by the contract, while the several lines, headed by the numbers of the proper stations, are devoted to the different cuttings, structures, etc., in consecutive order as they occur on the line of road. The estimates are made out and reported separately for the several sections into which the line of road is divided for letting.

These reports are reviewed by the division engineer, and the footings copied upon another blank, which is the monthly estimate proper; the prices are attached to the items, and the amounts extended and summed up. This sum indicates approximately the total amount earned by the contractor up to date, from which is deducted a certain percentage (usually 15 per cent), which is retained by the company until the completion of the contract. From the remainder is deducted the amount of previous payments, which leaves the amount due the contractor on the present estimate. A blank form of receipt is appended, to be signed by the contractor.

CHAPTER XVII

TRACK LAYING

311. After the roadbed has been prepared, the ties and rails are laid to approximate line, thus enabling the ballast train to enter. Ballast is deposited in layers of about 6 to 8 inches and the track is gradually raised and brought into position, both horizontally and vertically. To secure this two sets of stakes are used; the center line stakes, and the grade stakes.

312. Center Line Stakes. On long tangents, one stake in every 200 feet is sufficient; on ordinary curves, one stake in every 50 or 100 feet, and on very sharp curves one in every 25 feet. Having located the center stakes, the rails are brought into position by use of the track gauge.

The center point of the track gauge is placed at the tack in a stake, and the gauge sides of the rails are brought into contact with the lugs at the ends of the gauge. The rails at other stakes are similarly adjusted and the track between successive points is lined up by eye, whether on tangent or curve.

313. Curving Rails. Before any rail is spiked to its place in a curve, it must be evenly bent from end to end, so that it will assume the proper curvature when lying free. The bending may be done by using sledges, but is best accomplished, especially for turnouts and other sharp curves, by using a bending machine made especially for this purpose.

The proper ordinates for locating or bending curved rails may be found in different ways, of which some of the more usual will be given in the next two sections.

314. *To find the* **middle ordinate** m, **for 1 station,** *or* 100 *feet, on any curve, in terms of the degree of curve* D.

Referring to Fig. 144 we have in the right triangle AGH

$$GH = GA \cdot \tan \mathrm{GAH}$$

But $GA = \frac{1}{2}AB = \frac{1}{2}C$, and (Table XLI, 18) $GAH = \frac{1}{2}AOB = \frac{1}{2}\Delta$; hence

$$M = \tfrac{1}{2}C \cdot \tan \tfrac{1}{2}\Delta \qquad (368)$$

a general expression for the middle-ordinate of any chord.

If in this equation we make $C = 100$, Δ becomes D; and denoting the corresponding value of M by m, we have

$$m = \tfrac{1}{2}100 \tan \tfrac{1}{2}D \qquad (369)$$

whence the **rule,** *Multiply the nat. tangent of ½ the degree of curve by* 100 *and divide by* 2. Thus the values of m in the 5th column of Table I have been calculated.

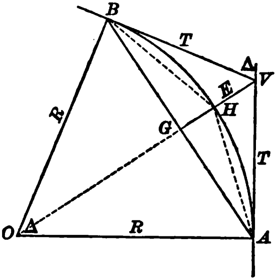


FIG. 144.

315. *To find the* **middle ordinate** *for any chord* **in terms of the chord** *and radius.*

Referring to Fig. 144, we have

$$GH = OE - OG = OE - \sqrt{AO^2 - GA^2}$$

or

$$M = R - \sqrt{R^2 - \left(\frac{c}{2}\right)^2} \qquad (370)$$

When $C = 100$ we have for the middle-ordinate of one station

$$m = R - \sqrt{R^2 - 2500} \qquad (371)$$

For any subchord c, less than 100, we have for the middle

inate,

$$\left.\begin{aligned} & m_1 = R - \sqrt{R^2 - \left(\frac{c}{2}\right)^2} \\ \text{or} \quad & m_1 = R - \sqrt{\left(R + \frac{c}{2}\right)\left(R - \frac{c}{2}\right)} \end{aligned}\right\} \qquad (372)$$

By adding $\frac{c^4}{64R^2}$ to the quantity under the radical in eq. (372) it becomes a perfect square, giving

$$m_1 = \frac{c^2}{8R} \text{ nearly,} \qquad (373)$$

which is a very useful formula, although approximate. The error in m_1 does not exceed .002 for any subchord c when the radius is greater than 800. On a 20° curve the error will be .002 for a chord of 50 feet; and on a 40° curve the error in m_1 will be only .003 for a chord of 33 feet. Equation (373) is therefore practically correct in all cases *for finding the middle-ordinates of rails.* Table VIII is calculated by eq. (372).

From the last equation it appears that, with a given radius, the middle ordinate varies nearly as the square of the chord. We may therefore find the middle ordinate of a rail whose length is c by the proportion

$$(100)^2 : c^2 :: m : m_1$$

or,

$$m_1 = \frac{c^2 m}{10000} \text{ nearly,} \qquad (374)$$

in which m is obtained from Table I, column 5, for the given radius of degree of curve.

Example.—What is the middle ordinate of a 33-foot rail when curved for a 20° curve?

$$\text{Eq. (374)} \qquad m_1 = \frac{1089 \times 4.374}{10000} = 0.476 = 5\tfrac{11}{16} \text{ in.}$$

When a long rail is bent for a sharp curve, observe that c is the length of the chord of the rail—not of the rail itself.

For the chord of half a rail the middle ordinate is one-fourth the middle-ordinate of the whole rail. Thus, in the above example it would be 0.119 or $1\tfrac{7}{16}$ inches.

Instead of *using the* chord of the whole rail, it may be mor *convenient to assume* a chord shorter than the rail, especia when the chord is not an exact number of feet, knotting the string to the length assumed, and applying it to different portions of the rail successively.

316. Testing Track Curvature. The proper curvature of a rail is tested by measuring its middle-ordinate from a small cord stretched from end to end and touching the side of the rail-head. The cord should also be stretched from the middle point of the rail to either end, and the middle-ordinate of each half length measured, to test the *uniformity* of curvature.

A common rule for finding the degree of curve of a track is "*The middle-ordinate in inches of a 62-foot chord equals the degree of curve.*" This follows from eq. (373) by substituting 1 inch for m, and 5730 for the radius of a 1° curve. Assuming that the radius varies directly as the degree of curve, the rule obtains as stated.

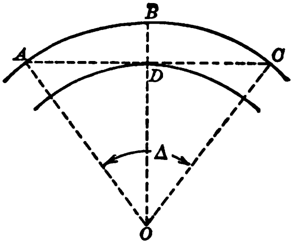


FIG. 145.

Another method is illustrated by Fig. 145.

Select a point A at a rail joint; sight along a fine tangent to the inner rail at a point as D, and note its intersection with the other rail at C. Count the number of rail lengths whole and fractional in ABC.

Let n denote the number of rail lengths in ABC.

Combining eq. (373) and $R = \frac{5730}{D}$, and solving for D [illegible]e get

$$D = \frac{8 \times 5730 m_1}{c^2}$$

Considering the lengths of the chord AC and the arc ABC equal, we have for 30-foot rails, $c = 30n$, and for 33-foot rails $c = 33n$.

This equation for the standard gauge of 4 feet 8½ inches = 4.708 feet becomes for 30-foot rails

$$D = \frac{240}{n^2} \text{ (approx.)} \tag{375}$$

and for 33-foot rails

$$D = \frac{198}{n^2} \text{ (approx.)} \tag{376}$$

Equations (375) and (376) give the degree of the outer rail, and that only roughly, depending on the *actual gauge,* which is sometimes increased on curves.

317. Grade stakes are placed at one side of the track. The tops of the stakes are set for the grade of the top of the rail, which is at a certain definite height above the " subgrade " of the profile and cross-sections.

Track on tangents is level transversely. If the grade is uniform, the elevation of stations differ by a constant amount. On curves, the top of the stake indicates the elevation for the outer rail, the inner rail carrying the regular grade.

The track is gradually raised by track jacks and by tamping until it is at the proper elevation, as proved by a track level extending from the top of a stake to the top of the rail.

318. Vertical Curves. The established grades of a road appear on the profile as right lines which are either level or else so inclined as to have a definite rate of rise per station, and as a station measures 100 feet, this rate is often described as a percentage, a grade rising 1 foot per station being known as a 1 per cent grade, for instance. The chosen grade must not only have a definite rate, but it must terminate at a station (rarely at a half-station) where it meets another right-line grade and makes with it a definite angle. This angle, however, is not estimated in degrees, but by the difference in the rates of the grades.

If the grades—both of them rising—have the respective rates of g and g', the angle is expressed by $(g - g')$. Grades rising in the direction in which the survey was made are marked and called +, and grades falling in the same direction are called −, but the above expression is always tru algebraically. If both grades were −, their difference would still define the angle, but if one were rising and the other falling, then the *sum* of the rates, either *plus* or *minus*, would define the angle between the grades.

For the safety and convenience of the traffic this angle must be replaced by a vertical curve, tangent to the grade lines, the total angle being distributed among its chords. The parabola is always used for vertical curves, and the tangent points must be fixed at equal distances from the vertex so that the diameter through the vertex, and all offsets parallel to it, may be vertical. The curve must be long enough to make the transition easy. As heavy trains reach the top of a long grade at a lower speed than that with which they reach its foot, it is customary to allow much shorter curves at summits than at sags.

To determine the length of a vertical curve, let n be the number of stations in the curve, and $2a$ the linear deflection from chord to chord thought desirable. Then

$$n = \frac{g - g'}{2a} \tag{377}$$

If this value of n is fractional, take the nearest *even* number (preferably greater), as the final value of n. Then by inversion,

$$a = \frac{g - g'}{2n} \tag{378}$$

which is the linear deflection from the grade tangent to the first station on the curve at either end, since a tangent deflection is one half the chord deflection.

The values of a and n being decided, it is a simple arithmetical operation to tabulate the elevations of the stations of the curve, as will appear from the following:

319. *Example.*—Fig. 146. *Given*, a rising grade of 0.8 to station V; thence a falling grade of 0.4; to join the grades with a vertical curve in which $2a = 0.20$, and let the elevation of V be 117.0 feet.

By eq. (377)

$$n = \frac{+0.80 - (-0.40)}{0.20} = 6, \text{ and each tangent} = 3.$$

Then

$$117.0 - 3 \times 0.8 = 114.6 = \text{elevation of sta. } A,$$

and

$$117.0 - 3 \times 0.4 = 115.8 = \text{elevation of sta. } C.$$

Calling sta. *A* zero, and numbering the curve stations from 0 to 6, we prepare the following statement:

Sta.	Defl.	Cor.	Rate	Elev.	Sta.
0		0	+.8	114.6	*A*
1	*a*	−.1	+.7	115.3	*K'*
2	2*a*	−.2	+.5	115.8	*L'*
3	2*a*	−.2	+.3	116.1	*B*
4	2*a*	−.2	+.1	116.2	*M'*
5	2*a*	−.2	−.1	116.1	*N'*
6	2*a*	−.2	−.3	115.8	*C*
	a	−.1	−.4	tangent	

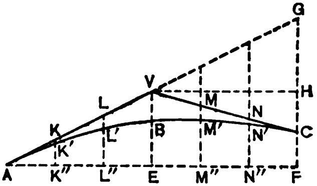


FIG. 146.

The elevation of each station is obtained from the preceding after correcting the rate, and the last rate would give the elevation of the next station on the grade beyond *C*. This, and the elevation of *C* proves the statement correct.

Had the first grade been a descending one its rate would have been *minus* and the corrections *plus*. Otherwise the operation would be the same. The elevations are the grades at the several stations by which grade stakes are set, either for the original cross-sectioning or for final test.

If it is desired to set grade stakes every 50 feet we have but to double the value of *n* and halve the value of *g* and of *a*, and proceed as before.

This solves the whole problem; but there are other ways of arriving at the same results, which will be noticed briefly, as they are preferred by some.

320. It is a property of the parabola that offsets from tangent to curve are to each other as the square of the *distance from the tangent point.* Hence, if we call *l* and number the stations in order up the grade tangent, we shall have in the example given above:

Station	*A*	1	2	3	4	5	6
Offset	0	*a*	4*a*	9*a*	16*a*	25*a*	36*a*
Offset	0	.1	.4	.9	1.6	2.5	3.6
Tan. Grade	114.6	115.4	116.2	117.0	117.8	118.6	119.4
Curve Grade	114.6	115.3	115.8	116.1	116.2	116.1	115.8
Station	*A*	*K'*	*L'*	*B*	*M'*	*N'*	*C*

In this method the grade tangent is produced from *V* to *G* and the last offset is represented in the figure by the line *GC*, which is just four times the length of *VB*.

This method may be somewhat simplified, especially on a very long curve, by observing that the figure is symmetrical about the diameter *VE* drawn through the vertex, so that *MM'* = *LL'*, etc. Therefore, after the point *V* we may write the elevations of the succeeding stations on the second tangent and apply to them the offsets already obtained, but in reverse order. The result is the same.

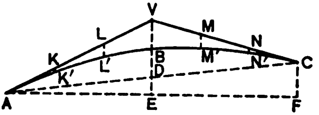


FIG. 147.

321. A third method of computing grade elevations on vertical curves is by means of a vertical ordinate from the long chord, *AC*, Fig. 147. The elevation of the middle point of this chord is a mean of the elevations of grade at *A* and *C*. Thus we obtain *VD*, which the parabola bisects at *B*, giving us the middle-ordinate, *DB* = *VB*, or

$$VB = \tfrac{1}{2}\left(\text{grade } V - \frac{\text{grade } A + \text{grade } C}{2}\right) \qquad (379)$$

Divide *AV* into any number of equal parts and divide *VB by the* square of the number, and the quotient is the *ertical* offset from tangent to curve at the first point from ther offsets are proportional to the square of their distance from A as in the former case. Treat VC in the same manner; the offsets will be the same for the same number of points.

322. As to desirable values for the linear deflection, $2a$, the Am. Ry. Eng. Association has recommended the limits of 0.10 on summits, and 0.05 in sags for first-class roads with heavy traffic, while for minor roads with light traffic these limits may safely be doubled. It would be well to change the above limit of 0.05 to 0.06 in order to avoid the third decimal place in figuring grades.

323. Elevation of the Outer Rail on Curves. When a car passes around a curve, a centrifugal force is developed which presses the flanges of the wheels against the outer rail. This force acts horizontally, and varies as the square of the velocity, and inversely as the radius of the curve. Denoting the centrifugal force by f, we have from the theory of mechanics $f = \frac{wv^2}{32.166R}$, in which w = weight of loaded car in pounds, v = velocity in feet per second, and R = radius of curve in feet.

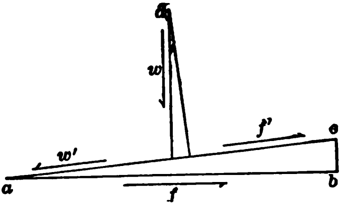


FIG. 148.

In Fig. 148 let ab represent a level line at right angles to the track, let a and c be the tops of rails on a curve, let $bc = e$ = elevation of outer rail c, and let the point d be the center of gravity of the car. The force f acts in the direction ab, and if f' = the component of f in the direction ac, then

$$f' : f :: ab : ac.$$

The weight w, resting on the inclined plane ac develops a component in the direction ca, and denoting this by w', we have by similar triangles,

$$w' : w :: bc : ac.$$

Since equilibrium requires that w' shall equal f', we have after dividing one proportion by the other $\frac{f}{w} = \frac{bc}{ab}$, or $f = \frac{w \cdot e}{ab}$. Equating this value of f with that given above we find,

$$e = \frac{ab \cdot v^2}{32.166R}$$

But $ab = \sqrt{ac^2 - e^2}$, and ac = distance between rail centers = gauge + one rail head = $g + 0.188$. Also $v = \frac{5280}{3600}V$, if V denotes the velocity in miles per hour. Making these substitutions and reducing, we have

$$e = (g + .188)\frac{.06688\frac{V^2}{R}}{\sqrt{1 + \left(.06688\frac{V^2}{R}\right)^2}} \tag{380}$$

By this formula Table IX is calculated for the standard gauge $g = 4'\,8\frac{1}{2}''$, $= 4.708$.

An approximate formula may be obtained by assuming that $ab = g$ for practicable values of e. Substituting this in the first value of e given above, and replacing v by $\frac{5280}{3600}V$ we have

$$\text{(approx.)} \qquad e = .06688\frac{gV^2}{R} \tag{381}$$

which is the formula generally employed.

In laying a new track, the transverse inclination is first given to the ballast by grade pegs driven either side of the center line at a distance of $(g + .188)$ each side of the center; the outside peg being set higher, and the inside peg lower than the grade of ballast on the center line, by the proper elevation selected from Table IX. But in resurfacing an old track, the inner rail is taken as grade and the outer rail is raised the necessary amount.

324. *The proper* **elevation** may be **found mechan-**[illegible] *by the following method:*

nd on a curved track, the length of a chord whose middle-

ordinate shall equal the proper elevation of the outer rail for any velocity V in miles per hour.

By the conditions of the problem, we have m_1 in eq. (373) equal to e in eq. (381), or

$$\frac{c^2}{8R} = \frac{gV^2.06688}{R}$$

$$\therefore \qquad c = .73144V\sqrt{g} \qquad (382)$$

When $g = 4.708$,

$$c = 1.587V \qquad (383)$$

Lay off the chord, c, upon the rail of the track, stretch a piece of twine between the points so found, and measure the middle-ordinate; it will equal the proper elevation.

325. The velocity assumed in the preceding formulas should be that of the fastest regular trains which will pass over the curve in question, since the flanges would be forced against the outer rail were there no centrifugal force developed, by reason of the wheels being rigidly attached to the axles, and the axles being parallel.

The rails on tangents should be level transversely except on very flat curves where spirals are not employed. In such cases one rail of the tangent is gradually elevated, beginning a short distance from the P.C. and the P.T. At a P.C.C. the elevation should be an *average* of the elevations due to the two arcs. Owing to the difficulty of properly adjusting the elevation of rail, it is objectionable to have arcs of very dissimilar radii join each other; and the objection is much greater in the case of reversed curves unless separated by a short tangent. See § 82.

On the other hand, a short tangent between arcs which curve in the same direction should be avoided, since it makes a "flat place" both in line and levels, at once unsightly and injurious to the rolling stock.

In the case of turnouts, however, no elevation of rail is possible (except when both tracks curve in the same direction).

326. Owing to the **expansion of the rails** by heat, a space must be left at the rail-joints. The highest temperature of a rail in the summer sun is about 130° Fahr. The expansion of iron and steel per 100° is .0007 per foot; or a 33-foot rail .023 foot or .276 inch. Therefore whe foot rails are laid at a temperature near the freezing-point, or 100° below the maximum, the space allowed must be at least a quarter of an inch. At 80° Fahr. or 50° below the maximum, it need be only half as much. The space required is also proportional to the length of rail used. The exact space should be given, as less would result in the rails being forced up by expansion, while more than necessary space gives a rough road, and hastens the destruction of the rail.

Wherever **sidings** are required, the necessary frogs and long switch-ties should be provided in advance, so that they may be put in place at the time of laying the main track. For every road crossing at grade, heavy oak plank should be provided, and laid upon the ties as soon as the rails are spiked, so that the highway travel may not be impeded.

CHAPTER XVIII

TOPOGRAPHICAL SKETCHING

327. Topographical sketches taken on preliminary surveys are usually of great value in projecting a line for location; they should be made therefore as accurate and complete as possible. In too many instances sketches are presented having a picturesque appearance, but conveying little information, if not tending to mislead the map-maker. The aim of the topographer should be to record the topographical features either side of the line with as much precision as those directly upon the line, without taking actual measurements, except in rare instances. The eye and the judgment must be usually depended on for distances and dimensions. The sketch of a tract extending to 400 feet each side of the line ought to be accurate enough to warrant its being copied literally upon the map. If a much wider range is required it may be advisable to use the plane-table; but an approximation to plane-table methods may be employed in ordinary sketching.

328. As **artificial features** are the most readily defined and located, these should first receive attention in making a sketch. When recorded they form a skeleton upon which the natural features can be drawn with more precision than if the order were reversed. The point where each fence crosses the line and the angle between the two may be sketched exactly. The distance along the fence to any object may be estimated, and checked (in case of an oblique angle) by observing where a line from the object perpendicular to the center line would intersect the latter. The book may be rested on any support, the center line of the page coinciding with the line of survey, and the direction of objects defined by a small ruler laid on the page. This operation being repeated from another point gives intersections which locate the several objects on the sketch.

If the bearings are taken they may be plotted on the page as well as recorded, giving the same results. The eye may be trained to estimate distances correctly by observing the appearance of objects along the measured line, the distances to which are therefore known.

329. After the artificial objects the more distinct **natural features** are to be sketched, as streams, shores, margins of swamps, forests, etc., ravines, ridges, and bluffs, taking care that all these outlines intersect the features of the sketch already delineated at the proper points. The correct representation of **contours** is the most difficult part of sketching, since these lines are quite imaginary, yet for railroad maps they are usually as important as any others. It is desirable to know not only the locality of a hill or slope, but also its shape, steepness, and height. This information is best given by contour lines. A contour is the intersection of the surface of the ground by an imaginary level surface. When the surface is real, like that of a lake, the intersection is called a shore. If the water should rise a certain height a new shore would be defined, and rising double that height still another shore would result, each of which, on the subsidence of the water, would be a contour. A practiced eye is able to follow on the ground the course of a contour with all its windings; but in sketching them due allowance must be made for the foreshortening effect of distance. All contours on the same sketch should have the same vertical interval, so that by counting them the height of the hill may be known. The spaces on the sketch between contours vary as the cotangent of the slope angle, so that the width of the spaces indicates the degree of steepness. The contours nearest the topographer should generally be sketched first, although if there be a shore that is apt to be the best guide to the shape of the slopes. If the height of the hill is known and the upper contour located, the other contours can be spaced between with less difficulty, the proper number being ascertained by dividing the height by the assumed vertical interval. A special line of levels up an inclined ravine or sloping ridge to fix the contour points is often of the greatest service in [illegible]ining correct results. Other random lines are sometimes [illegible] *locate* the contours more definitely. These should [illegible]de *to* cross several contours rather than to trace a single one. Old preliminary lines which have proved useless in themselves often furnish by their profiles valuable information in respect to contours.

The use of hatchings should be avoided in the sketch-book, except to represent precipitous banks, or slight terraces, which would not be sufficiently defined by the contour system. Hatchings freely used consume too much time, and fail to give an accurate idea of either slope or height, while they obscure the page for the representation of other objects.

330. The center line on the page is straight, and for sketching purposes the surveyed line on the ground is assumed to be so also. Slight deflections in the course of a preliminary line may be ignored in the sketch; but if a large angle occurs it is better to terminate the sketch with the course, and begin again, leaving a few blank lines between the two sketches. On a located line with curves, the sketch is continuous. The curved line in the field is represented by the straight line on the page, and the radial lines through the stations are represented by the parallel lines ruled across the page. All objects are sketched at the proper offset distance by scale from the center line; but longitudinally the sketch is necessarily diminished outside of the curve, and magnified inside of the curve. Consequently topographical lines which are straight in fact appear curved in the sketch, concave to the center line if inside the curve, and convex if outside of it. Such features are correctly sketched by means of offsets estimated or measured from each station of the curve on the radial lines. This kind of distortion creates no confusion if properly done, for in making the map, after drawing the curve and the radial lines, the same offsets will give the correct positions of the objects delineated. This method is preferable to drawing a curved line on the page to represent the center line, as it is difficult to draw it correctly; it will cross the ruled lines obliquely, rendering them of no service for offsets or scales, and moreover is likely to run off the page altogether.

CHAPTER XIX

ADJUSTMENT OF INSTRUMENTS

EVERY adjustment consists of two processes: first *the test*, and second *the correction.* Inasmuch as the amount of correction is made by estimation, the test must always be repeated until no further lack of adjustment is observable.

THE TRANSIT

331. The level tubes should be parallel to the vernier plate.

Test: Place the tubes in position over the leveling screws, and turn the latter till the bubbles are centered; turn the plate half way around until the tube is parallel to the same pair of screws. The bubbles should remain centered; if they have retreated—

Correction: Bring them half way back to the center by turning the adjusting screws which attach the tubes to the plate.

The line of collimation should be perpendicular to the horizontal axis.

Test: Clamp the limb, and by the tangent screws bring the intersection of the cross-hairs to cover a well-defined point about on a level with the telescope: plunge the telescope to look in the opposite direction, and note any point about on a level with the telescope and about equidistant with the first point, which the intersection of the cross-hairs now happens to cover. Now unclamp the limb and turn the telescope in azimuth, and repeat the above operation, using the same *first* point as before.

The *third* point obtained should be identical with the *second*; if not—

Correction: Move the vertical cross-hair over *one fourth* of the apparent distance from the third to the second point, *by* turning the adjusting screws at the side of the telescope.

The horizontal axis should be parallel to the vernier plate.

Test: After completing the above adjustments level the limb, clamp it, and bring the intersection of the cross-hairs to cover some high point so that the telescope may be elevated to a large angle; depress the telescope and note some point on the ground now covered by the intersection of the cross-hairs. Now unclamp the limb, turn the telescope in azimuth and repeat the above operation, using the same high point as before. The third point found should be identical with the second; if not—

Correction: Raise the end of the axis opposite the second point (or lower the other end) by a small amount, by turning the adjusting screws in the standard. The amount of motion required is determined only by repeated trials until the test is satisfied.

The intersection of the cross-hairs should appear in the center of the field of view.

Test: Bring the cross-hairs into focus and direct the telescope toward the sky, or hold a sheet of blank paper in front of it. If the intersection appear eccentric—

Correction: Turn the screws (by pairs) which support the end of the eyepiece until the desired result is obtained.

If there be **a level on the telescope** it **should be parallel to the line of collimation.**

Drive two stakes equidistant from the instrument in exactly opposite directions, and having perfected the previous adjustments, level the plate carefully, clamp the telescope in about a horizontal position, and observe a rod placed on each stake. Have the stakes driven by trial until the rod reads alike on both. The heads of the stakes are then on a level. Remove the instrument beyond one stake, and set it up in line with the two, level the plate, and elevate or depress the telescope to a position which will again give equal readings on the stakes. The line of collimation is now level—

Test: While in this position the bubble of the attached level should stand centered; if not—

Correction: Bring the bubble to the center by turning the nuts at one end of the tube, while the cross-hair continues to give equal readings.

THE Y LEVEL

332. The line of collimation should coincide with the axis of the telescope.

Test:. Clamp the spindle, and bring the intersection of the cross-hairs to cover a well-defined point by the tangent and leveling screws; revolve the telescope half over in the Y's, so that the level tube is on top. The intersection of the cross-hairs should still cover the point. If either hair has departed—

Correction: bring it half way back by means of the pair of adjusting screws at the extremities of the other hair.

The attached level should be parallel to the axis of the telescope.

Test: Bring the telescope over one pair of leveling screws, clamp the spindle, open the clips, and bring the bubble to the center. Then gently remove the telescope from the Y's, and replace it end for end. If the Y's have not been disturbed, the bubble should return to the center. If it does not—

Correction: bring the bubble half way back by turning the nuts at one end of the tube.

But as now the level tube and telescope may only lie in parallel planes, and yet not be parallel to each other—

Test: bring the bubble to the center as before, and turn the telescope on its axis so as to bring the level tube out to one side. The bubble should remain centered. If it has departed—

Correction: bring it back to the center by the adjusting screws at the side of the level tube.

The axis of the telescope should be at right angles to the spindle.

Test: Having completed the above adjustments (and not before), fasten down the clips, unclamp the spindle, and bring the bubble to the center over each pair of leveling screws in succession, then swing the telescope end for end on the spindle. The bubble should settle at the center. If it does not—

Correction: bring it half way back by the large nuts at [illegible] *end of the bar.*

THE DUMPY LEVEL

333. The telescope of the dumpy level cannot be taken from the Y's, consequently there are two adjustments only. These are:

The axis of the bubble should be at right angles to the axis of the spindle.

The *test* and *correction* are the same as for the plate level adjustment of the transit.

The attached level should be parallel to the axis of the telescope.

The *test* for this adjustment is the same as the corresponding one for the transit. The correction, however, is made by *changing the position of the reticule which carries the cross-hairs,* the level vial remaining the same.

APPENDIX.

Verification of eq. (77).

Eq. (76) $$\rho=\frac{\sin\theta}{\sin\frac{\theta}{N}}=\sin\theta\,.\,\text{cosec}\,\frac{\theta}{N}$$

$$\frac{d\rho}{d\theta}=\cos\theta\,.\,\text{cosec}\,\frac{\theta}{N}-\frac{1}{N}\,.\,\sin\theta\,.\,\cot\frac{\theta}{N}\,.\,\text{cosec}\,\frac{\theta}{N} \qquad (76\tfrac{1}{2})$$

$$\therefore \qquad \frac{d\rho}{d\theta}=\rho\left(\cot\theta-\frac{1}{N}\cot\frac{\theta}{N}\right) \qquad (77)$$

Verification of eq. (81).

Differentiating eq. (76½)

$$\frac{d^2\rho}{d\theta^2}=-\sin\theta\,\text{cosec}\,\frac{\theta}{N}-\frac{2}{N}\cos\theta\cot\frac{\theta}{N}\,\text{cosec}\,\frac{\theta}{N}+$$

$$\frac{1}{N^2}\sin\theta\cot^2\frac{\theta}{N}\,\text{cosec}\,\frac{\theta}{N}+\frac{1}{N^2}\sin\theta\,\text{cosec}^3\,\frac{\theta}{N}$$

$$=-\rho-\frac{2\rho}{N}\cot\theta\,.\,\cot\frac{\theta}{N}+\frac{\rho}{N^2}\left(\cot^2\frac{\theta}{N}+\text{cosec}^2\,\frac{\theta}{N}\right)$$

$$\frac{d^2\rho}{d\theta^2}=\rho\left(-1-\frac{2}{N}\cot\theta\cot\frac{\theta}{N}+\frac{1}{N^2}\left(2\cot^2\frac{\theta}{N}+1\right)\right)$$

Now
$$r = \frac{\left(\rho^2 + \frac{d\rho^2}{d\theta^2}\right)^{\frac{3}{2}}}{\rho^2 + 2\frac{d\rho^2}{d\theta^2} - \rho\frac{d^2\rho}{d\theta^2}}$$

in which substitute for $\frac{d\rho}{d\theta}$, and for $\frac{d^2\rho}{d\theta}$, and let

$$\cot\theta - \frac{1}{N}\cot\frac{\theta}{N} = -a$$

$$\frac{\left(\rho^2 + \rho^2(-a)^2\right)^{\frac{3}{2}}}{\rho^2 + 2\rho^2(-a)^2 - \rho^2\left(-1 - \frac{2}{N}\cot\theta\cot\frac{\theta}{N} + \frac{1}{N^2}\left(2\cot^2\frac{\theta}{N} + 1\right)\right)}$$

$$= \frac{\rho}{2} \cdot \frac{(1 + a^2)^{\frac{3}{2}}}{1 + a^2 + \frac{1}{N}\cot\theta \,.\, \cot\frac{\theta}{N} - \frac{1}{N^2}\cot^2\frac{\theta}{N} - \frac{1}{2N^2}}$$

$$= \frac{\rho}{2} \cdot \frac{(1 + a^2)^{\frac{3}{2}}}{1 - \frac{1}{2N^2} + a^2 + \frac{1}{N}\cot\frac{\theta}{N}\left(\cot\theta - \frac{1}{N}\cot\frac{\theta}{N}\right)}$$

$$= \frac{\rho}{2} \cdot \frac{(1 + a^2)^{\frac{3}{2}}}{1 - \frac{1}{2N^2} + a\left(a - \frac{1}{N}\cot\frac{\theta}{N}\right)}$$

$$r = \frac{\rho}{2} \cdot \frac{(1 + a^2)^{\frac{3}{2}}}{1 - \frac{1}{2N^2} - a\cot\theta}$$

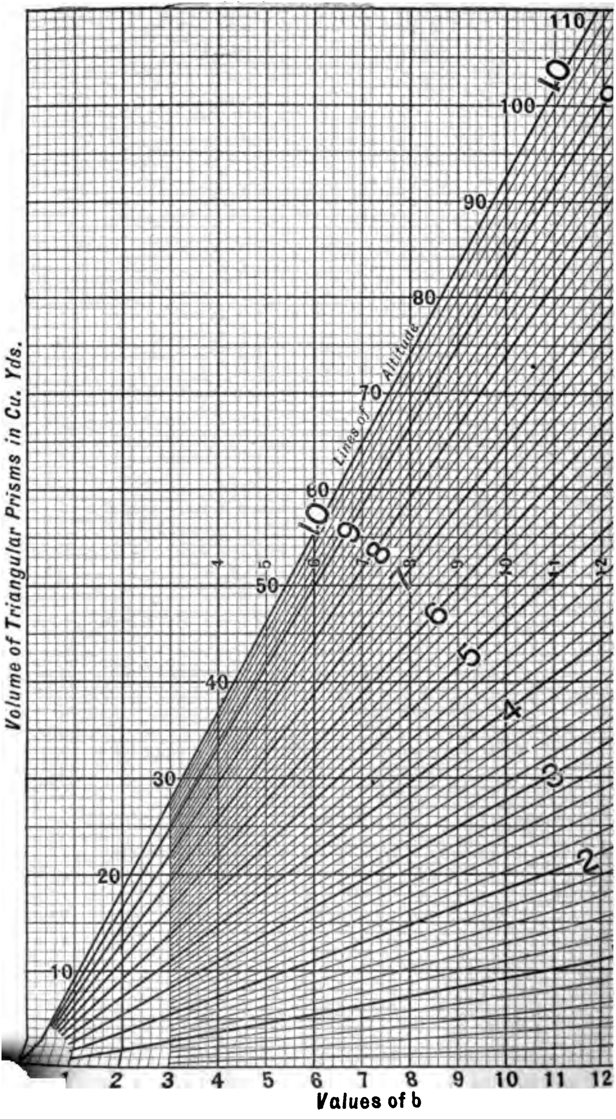
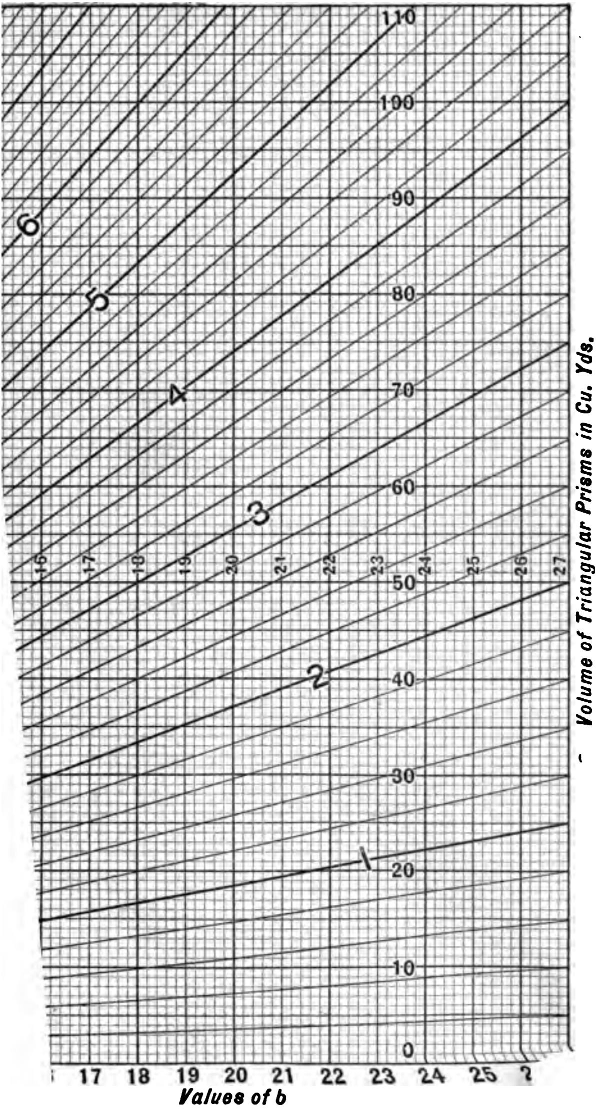

Volume of Triangular Prisms in Cu. Yds.
10
20
30
40
50
60
70
80
90
100
110
Lines of Altitude
10
9
8
7
6
5
4
3
2
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
Values of b

PLATE I. TRIANGULAR PRISMS



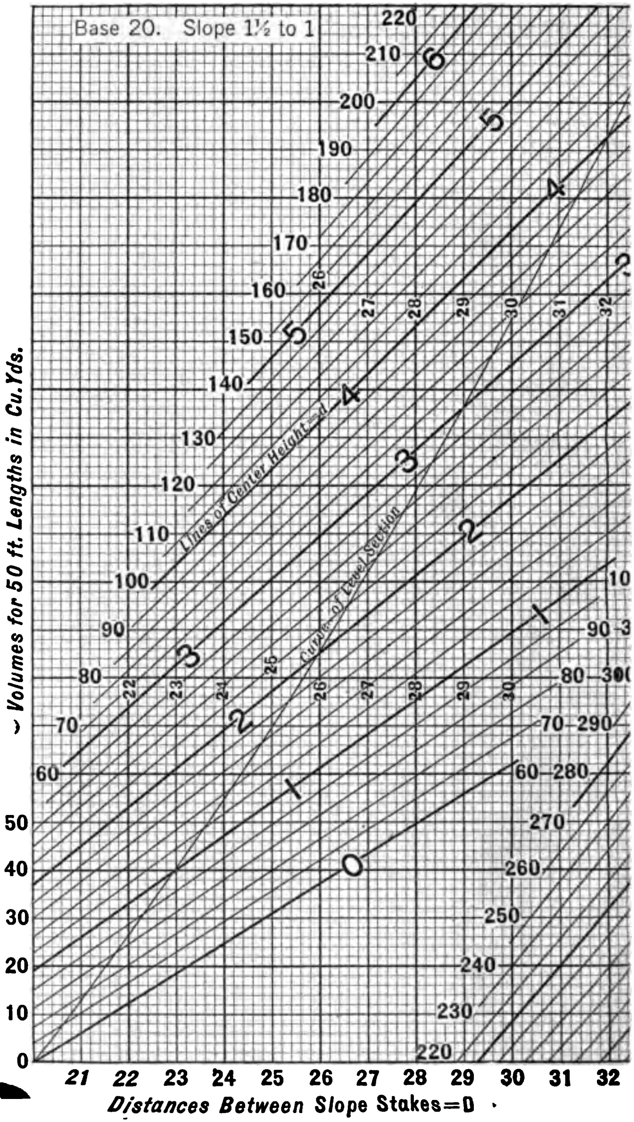
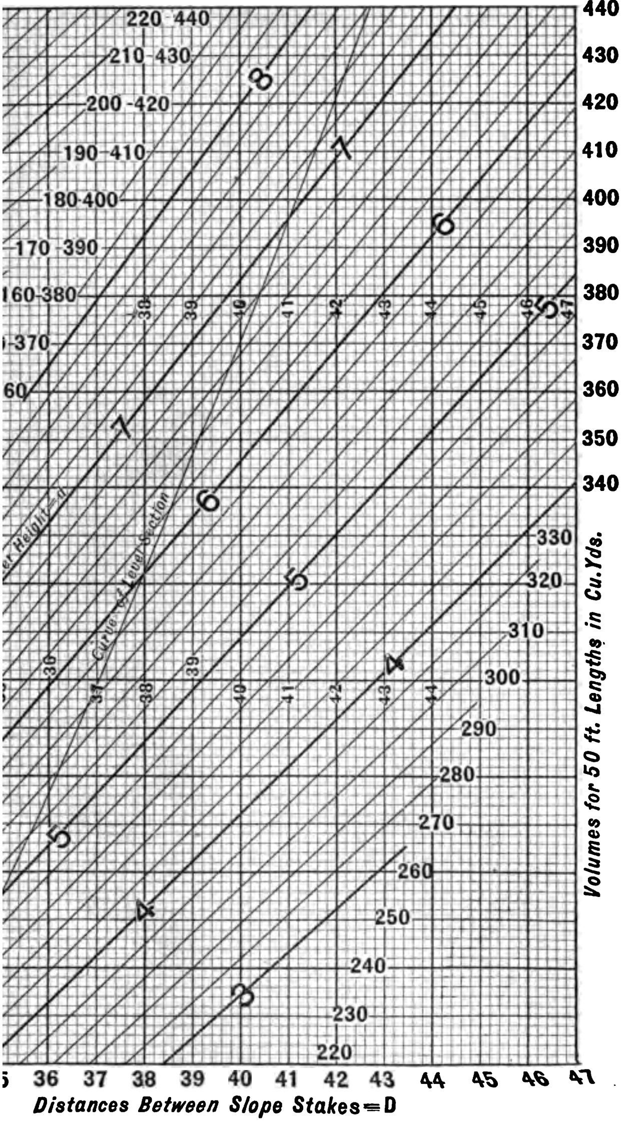

Base 20. Slope 1½ to 1
Volumes for 50 ft. Lengths in Cu.Yds.
Distances Between Slope Stakes=D
Lines of Center Height=d
Curve of Level Section
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
21
22
23
24
25
26
27
28
29
30
31
32
0
1
2
3
4
5
6

PLATE II. THREE LEVEL SECTIONS



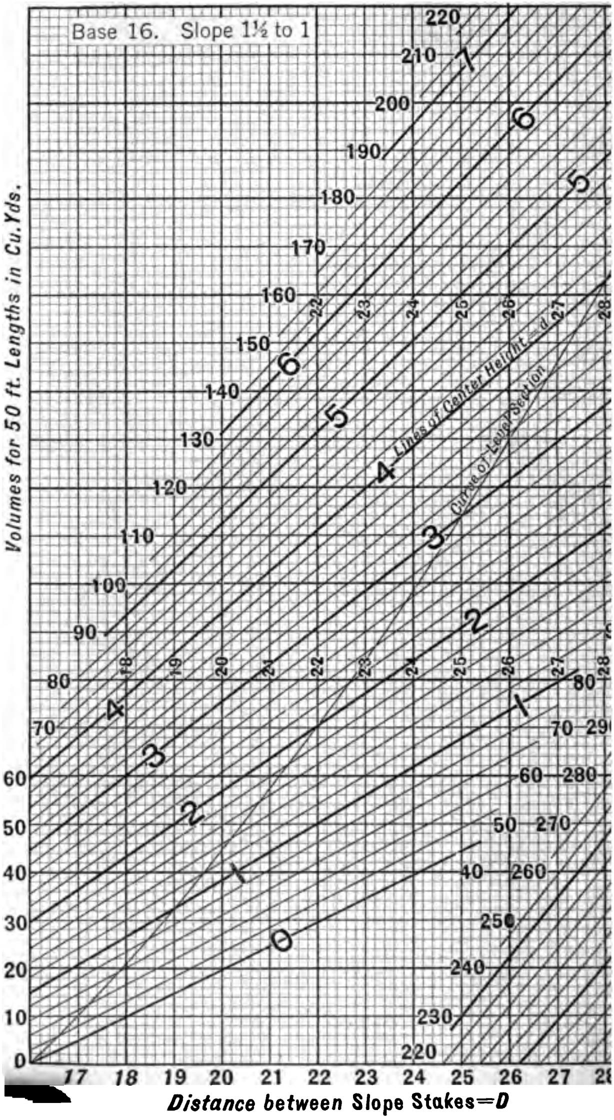
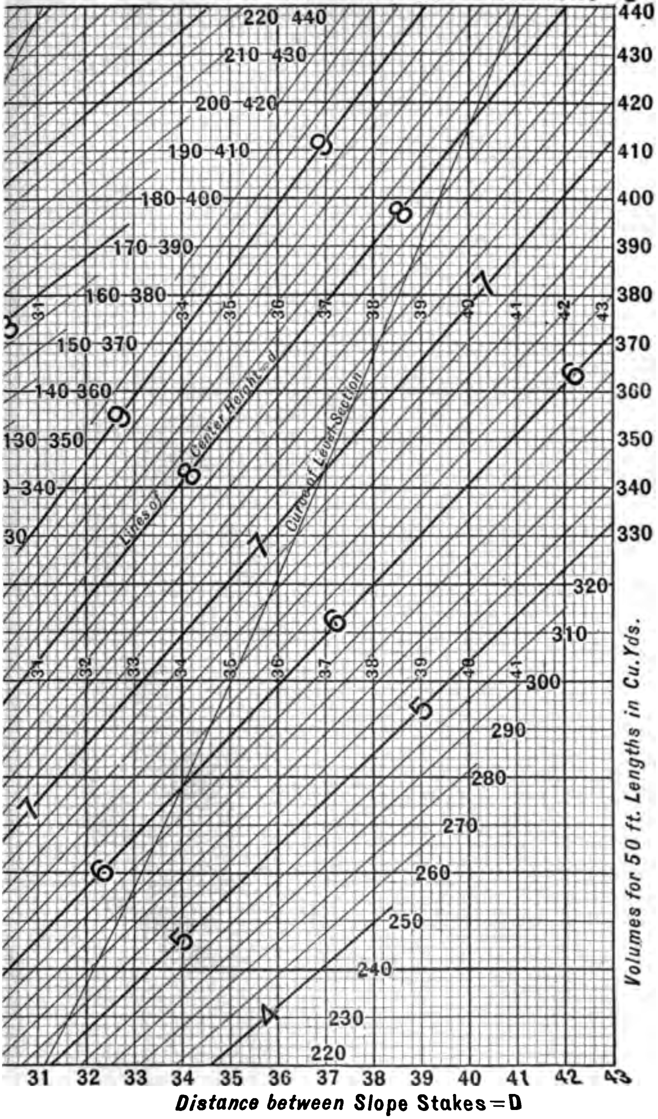

Base 16. Slope 1½ to 1
Volumes for 50 ft. Lengths in Cu.Yds.
Distance between Slope Stakes=D
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
220
230
240
250
260
270
280
80
70
60
50
40
17
18
19
20
21
22
23
24
25
26
27
0
1
2
3
4
5
6
7
Lines of Center Height = d
Curve of Level Section

PLATE III. THREE LEVEL SECTIONS



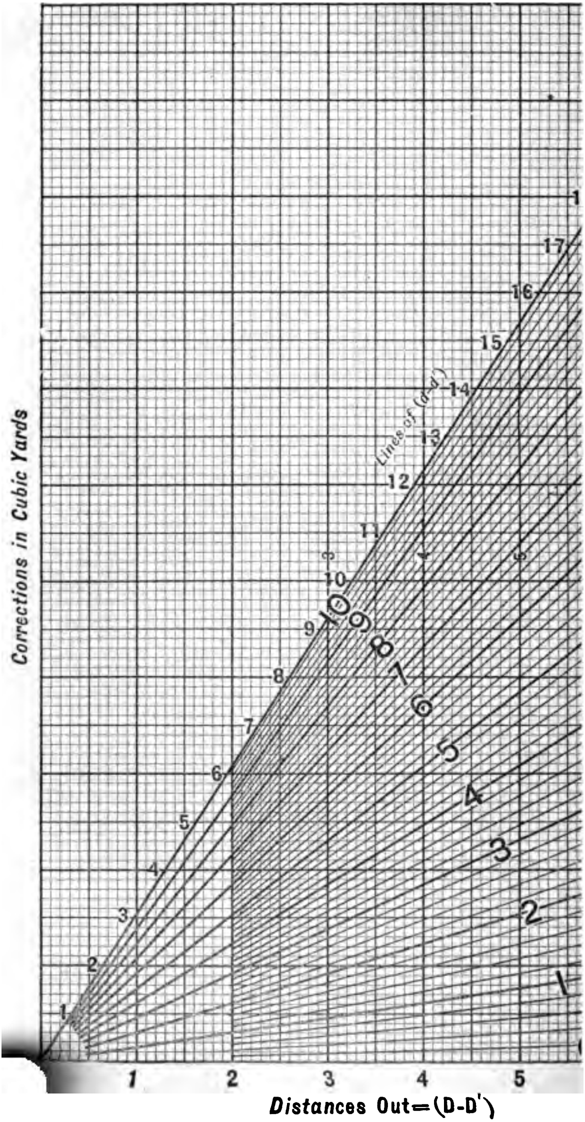
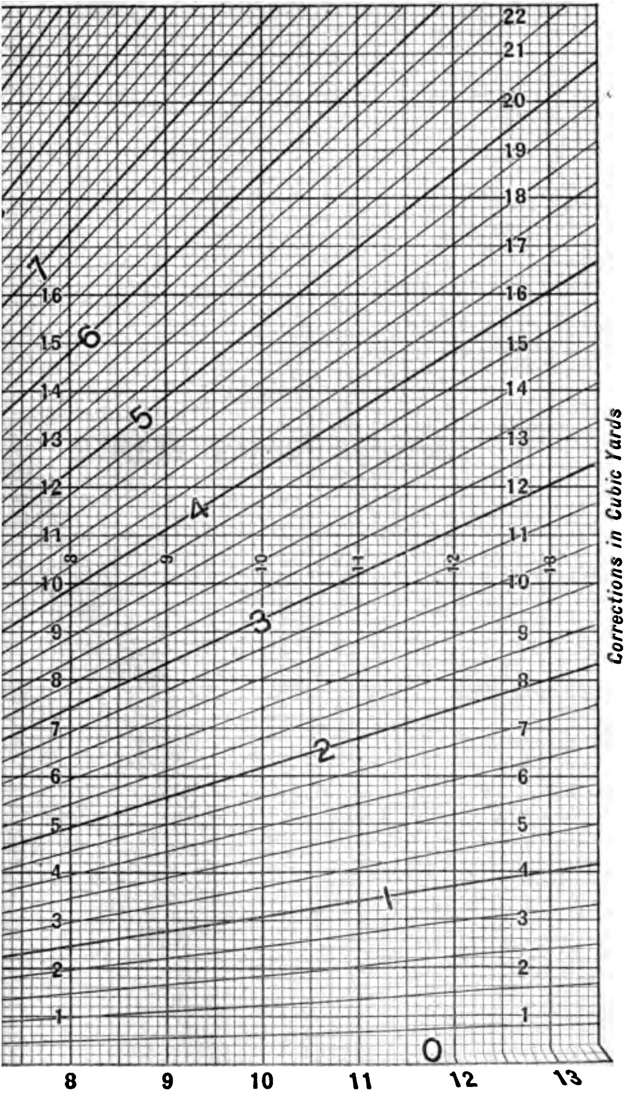

Corrections in Cubic Yards
Distances Out=(D-D')
1
2
3
4
5
Lines of (d-d')
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
1
2
3
4
5
6
7
8
9
10

PLATE IV. PRISMOIDAL CORRECTIONS



FIELD ENGINEERING

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A HANDBOOK OF THE

THEORY AND PRACTICE OF RAILWAY SURVEYING,
LOCATION AND CONSTRUCTION

BY

WILLIAM H. SEARLES, C.E.
Member American Society of Civil Engineers

EENTH EDITION, REVISED AND ENLARGE
TOTAL ISSUE, SIXTY-SEVEN THOUSAND

BY

THE LATE WILLIAM H. SEARLES

AND

HOWARD CHAPIN IVES, C.E.
Professor of Railroad Engineering, in the Worcester Polytechnic Institute

VOLUME II

TABLES

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PREFACE

THE tables are now published either separately or with the text.

In this edition sixteen new tables have been added. These are: Tables Nos. 11, 12, 13, 19, 22A, 22B, and 31 to 40 inclusive. Table 18 replaces two tables in the previous edition. Tables 8, 9, 43 and 44 have been either slightly changed or extended.

Tables 11, 12, 31 and 32 have been computed anew. Tables 34 to 40 inclusive are from Searles' "Railroad Spiral," somewhat extended and rearranged.

Acknowledgments are made to the American Railway Engineering Association for permission to use material in Tables 13, 22A, 22B, and 33; and to W. & L. E. Gurley for permission to use the material in Table 19, which is from their manual.

The following from the preface to the first edition applies to other tables.

Among the tables, Nos. 2, 3, 7, 26, 29 and 43 are original. The adoption of versed sines and external secants throughout the work, wherever these would simplify the formulas, rendered necessary the preparation of tables of these functions. The tables of logarithmic versed sines and external secants has been computed from ten-place logarithmic tables of sines and tangents, so that the last decimal is to be relied on, and no pains have been spared to make the table thoroughly accurate.

Tables Nos. 1, 4, 5, 6, 8, 9, 14, 22 and 30 have been recalculated, enlarged, and some of them carried to more decimal places than similar tables heretofore published. The intention has been to give one more decimal than usual, so that in any combination of figures the result of calculation might be reliable to the last figure usually required.

The tables which have been compiled and rearranged are Nos. 15, 16, 17, 24, 25, 41, 42 and 44. The tables of log sines and tangents here given are the only six-place tables which give the differences correctly for seconds. The table of logarithms of numbers is accompanied by a complete table of proportional parts, which greatly facilitates interpolation for the fifth and sixth figures.

In all the tables, whether new or old, scrupulous care has been taken to make the last figure correct, and the greatest diligence has been exercised by various checks and comparisons to eliminate every error. It is, therefore, hoped and believed that a very high degree of accuracy has been obtained, and that these tables will be found to stand second to none in this respect.

W. H. S.
H. C. I.

JULY, 1915.

PREFACE TO EIGHTEENTH EDITION

MANY requests for the inclusion of the American Railway Engineering Association Spiral having been made, it is presented in this edition. While discussing the same curve, the method of treatment is more or less original.

Acknowledgments are due the American Railway Engineering Association for permission to use this form of spiral, and for Tables XLVI and XLIX from the Manual of Recommended Practice. Tables XLV, XLVII and XLVIII have been computed in order to make the spiral easier of application.

OCTOBER, 1918.

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eg. D.	Radius. R.	Logarithm. log. R.	Tan. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.
0′	Infinite	Infinite	.000	.000	1° 0′	5729.65	3.758128	.873	.218
1	343775.	5 536274	.015	.004	1	5635.72	.750950	.887	.222
2	171887.	5.235244	.029	.007	2	5544.83	.743888	.902	.225
3	114592.	5.059153	.044	.011	3	5456.82	.736939	.916	.229
4	85943.7	4.934214	.058	.015	4	5371.56	.730100	.931	.233
5	68754.9	.837304	.073	.018	5	5288.92	.723367	.945	.236
6	57295.8	.758123	.087	.022	6	5208.79	.716737	.960	.240
7	49110.7	.691176	.102	.025	7	5131.05	.710206	.974	.244
8	42971.8	.633184	.116	.029	8	5055.59	.703772	.989	.247
9	38197.2	.582031	.131	.033	9	4982.33	.697432	1.004	.251
10	34377.5	4.536274	.145	.036	10	4911.15	3.691183	1.018	.255
11	31252.3	4.494881	.160	.040	11	4841.98	3.685023	1.033	.258
12	28647.8	.457093	.175	.044	12	4774.74	.678949	1.047	.262
13	26444.2	.422331	.189	.047	13	4709.33	.672959	1.062	.265
14	24555.4	.390146	.204	.051	14	4645.69	.667051	1.076	.269
15	22918.3	.360183	.218	.055	15	4583.75	.661221	1.091	.273
16	21485.9	.332154	.233	.058	16	4523.44	.655469	1.105	.276
17	20222.1	.305825	.247	.062	17	4464.70	.649792	1.120	.280
18	19098.6	.281002	.262	.065	18	4407.46	.644189	1.134	.284
19	18093.4	.257521	.276	.069	19	4351.67	.638656	1.149	.287
20	17188.8	4.235244	.291	.073	20	4297.28	3.633194	1.164	.291
21	16370.2	4.214055	.305	.076	21	4244.23	3.627799	1.178	.295
22	15626.1	.193852	.320	.080	22	4192.47	.622470	1.193	.298
23	14946.7	.174547	.335	.084	23	4141.96	.617206	1.207	.302
24	14324.0	.156064	.349	.087	24	4092.66	.612005	1.222	.305
25	13751.0	.138335	.364	.091	25	4044.51	.606866	1.236	.309
26	13222.1	.121302	.378	.095	26	3997.49	.601787	1.251	.313
27	12732.4	.104911	.393	.098	27	3951.54	.596766	1.265	.316
28	12277.7	.089117	.407	.102	28	3906.64	.591803	1.280	.320
29	11854.3	.073877	.422	.105	29	3862.74	.586896	1.294	.324
30	11459.2	4.059154	.436	.109	30	3819.83	3.582044	1.309	.327
31	11089.6	4.044914	.451	.113	31	3777.85	3.577245	1.324	.331
32	10743.0	.031125	.465	.116	32	3736.79	.572499	1.338	.335
33	10417.5	.017762	.480	.120	33	3696.61	.567804	1.353	.338
34	10111.1	4.004797	.495	.124	34	3657.29	.563160	1.367	.342
35	9822.18	3.992208	.509	.127	35	3618.80	.558564	1.382	.345
36	9549.34	.979973	.524	.131	36	3581.10	.554017	1.396	.349
37	9291.25	.968074	.538	.135	37	3544.19	.549517	1.411	.353
38	9046.75	.956493	.553	.138	38	3508.02	.545063	1.425	.356
39	8814.78	.945212	.567	.142	39	3472.59	.540654	1.440	.360
40	8594.42	3.934216	.582	.145	40	3437.87	3.536289	1.454	.364
41	8384.80	3.923498	.596	.149	41	3403.83	3.531968	1.469	.367
42	8185.16	.913027	.611	.153	42	3370.46	.527690	1.483	.371
43	7994.81	.902808	.625	.156	43	3337.74	.523453	1.498	.375
44	7813.11	.892824	.640	.160	44	3305.65	.519257	1.513	.378
45	7639.49	.883065	.654	.164	45	3274.17	.515101	1.527	.382
46	7473.42	.873519	.669	.167	46	3243.29	.510985	1.542	.385
47	7314.41	.864179	.684	.171	47	3212.98	.506908	1.556	.389
48	7162.03	.855036	.698	.174	48	3183.23	.502868	1.571	.393
49	7015.87	.846082	.713	.178	49	3154.03	.498866	1.585	.396
50	6875.55	3.837308	.727	.182	50	3125.36	3.494900	1.600	.400
51	6740.74	3.828708	.742	.185	51	3097.20	3.490970	1.614	.404
52	6611.12	.820275	.756	.189	52	3069.55	.487075	1.629	.407
53	6486.38	.812002	.771	.193	53	3042.39	.483215	1.643	.411
54	6366.26	.803885	.785	.196	54	3015.71	.479389	1.658	.414
55	6250.51	.795916	.800	.200	55	2989.48	.475596	1.673	.418
56	6138.90	.788091	.814	.204	56	2963.72	.471836	1.687	.422
57	6031.20	.780404	.829	.207	57	2938.39	.468109	1.702	.425
58	5927.22	.772851	.844	.211	58	2913.49	.464413	1.716	.429
59	5826.76	.765427	.858	.215	59	2889.01	.460749	1.731	.43
60	5729.65	3.758128	.873	.218	60	2864.93	3.457115	1.745	.4

Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.
6° 0′	955.366	2.980170	5.234	1.309	7° 0′	819.020	2.913295	6.105	1.528
1	952.722	.978966	5.248	1.313	1	817.077	.912263	6.119	1.531
2	950.093	.977766	5.263	1.317	2	815.144	.911234	6.134	1.535
3	947.478	.976569	5.277	1.320	3	813.219	.910208	6.148	1.539
4	944.877	.975375	5.292	1.324	4	811.303	.909183	6.163	1.543
5	942.291	.974185	5.306	1.327	5	809.397	.908162	6.177	1.546
6	939.719	.972998	5.321	1.331	6	807.499	.907142	6.192	1.550
7	937.161	.971814	5.335	1.335	7	805.611	.906125	6.206	1.553
8	934.616	.970633	5.350	1.338	8	803.731	.905111	6.221	1.557
9	932.086	.969456	5.364	1.342	9	801.860	.904098	6.236	1.561
10	929.569	2.968282	5.379	1.346	10	799.997	2.903089	6.250	1.564
11	927.066	2.967111	5.393	1.349	11	798.144	2.902081	6.265	1.568
12	924.576	.965943	5.408	1.353	12	796.299	.901076	6.279	1.572
13	922.100	.964778	5.422	1.356	13	794.462	.900073	6.294	1.575
14	919.637	.963616	5.437	1.360	14	792.634	.899073	6.308	1.579
15	917.187	.962458	5.451	1.364	15	790.814	.898074	6.323	1.582
16	914.750	.961303	5.466	1.368	16	789.003	.897078	6.337	1.586
17	912.326	.960150	5.480	1.371	17	787.200	.896085	6.352	1.590
18	909.915	.959001	5.495	1.375	18	785.405	.895094	6.366	1.593
19	907.517	.957855	5.510	1.378	19	783.618	.894105	6.381	1.597
20	905.131	2.956711	5.524	1.382	20	781.840	2.893118	6.395	1.600
21	902.758	2.955571	5.539	1.386	21	780.069	2.892133	6.410	1.604
22	900.397	.954434	5.553	1.389	22	778.307	.891151	6.424	1.608
23	898.048	.953300	5.568	1.393	23	776.552	.890171	6.439	1.611
24	895.712	.952168	5.582	1.397	24	774.806	.889193	6.453	1.615
25	893.388	.951040	5.597	1.400	25	773.067	.888217	6.468	1.619
26	891.076	.949915	5.611	1.404	26	771.336	.887244	6.482	1.622
27	888.776	.948792	5.626	1.407	27	769.613	.886272	6.497	1.626
28	886.488	.947673	5.640	1.411	28	767.897	.885303	6.511	1.630
29	884.211	.946556	5.655	1.415	29	766.190	.884336	6.526	1.633
30	881.946	2.945442	5.669	1.418	30	764.489	2.883371	6.540	1.637
31	879.693	2.944331	5.684	1.422	31	762.797	2.882409	6.555	1.641
32	877.451	.943223	5.698	1.426	32	761.112	.881448	6.569	1.644
33	875.221	.942118	5.713	1.429	33	759.434	.880490	6.584	1.648
34	873.002	.941015	5.727	1.433	34	757.764	.879534	6.598	1.651
35	870.795	.939916	5.742	1.437	35	756.101	.878580	6.613	1.655
36	868.598	.938819	5.756	1.440	36	754.445	.877627	6.627	1.659
37	866.412	.937725	5.771	1.444	37	752.796	.876678	6.642	1.662
38	864.238	.936633	5.785	1.447	38	751.155	.875730	6.656	1.666
39	862.075	.935545	5.800	1.451	39	749.521	.874784	6.671	1.670
40	859.922	2.934459	5.814	1.455	40	747.894	2.873840	6.685	1.673
41	857.780	2.933376	5.829	1.458	41	746.274	2.872898	6.700	1.677
42	855.648	.932295	5.844	1.462	42	744.661	.871959	6.714	1.680
43	853.527	.931218	5.858	1.466	43	743.055	.871021	6.729	1.684
44	851.417	.930142	5.873	1.469	44	741.456	.870085	6.743	1.688
45	849.317	.929070	5.887	1.473	45	739.864	.869152	6.758	1.691
46	847.228	.928000	5.902	1.476	46	738.279	.868221	6.773	1.695
47	845.148	.926933	5.916	1.480	47	736.701	.867291	6.787	1.699
48	843.080	.925869	5.931	1.484	48	735.129	.866363	6.802	1.702
49	841.021	.924807	5.945	1.487	49	733.564	.865438	6.816	1.706
50	838.972	2.923747	5.960	1.491	50	732.005	2.864514	6.831	1.710
51	836.933	2.922691	5.974	1.495	51	730.454	2.863593	6.845	1.713
52	834.904	.921637	5.989	1.498	52	728.909	.862673	6.860	1.717
53	832.885	.920585	6.003	1.502	53	727.370	.861755	6.874	1.720
54	830.876	.919536	6.018	1.505	54	725.838	.860840	6.889	1.724
55	828.876	.918489	6.032	1.510	55	724.312	.859926	6.903	1.728
56	826.886	.917446	6.047	1.513	56	722.793	.859014	6.918	1.731
57	824.905	.916404	6.061	1.517	57	721.280	.858104	6.932	1.735
58	822.934	.915365	6.076	1.520	58	719.774	.857196	6.947	1.739
59	820.973	.914329	6.090	1.524	59	718.273	.856290	6.961	1.742
60	819.020	2.913295	6.105	1.528	60	716.779	2.855385	6.976	1.746

Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.
8° 0′	716.779	2.855385	6.976	1.746	9° 0′	637.275	2.804327	7.846	1.965
1	715.291	.854483	6.990	1.749	1	636.099	.803525	7.860	1.968
2	713.810	.853583	7.005	1.753	2	634.928	.802724	7.875	1.972
3	712.335	.852684	7.019	1.756	3	633.761	.801926	7.889	1.975
4	710.865	.851787	7.034	1.760	4	632.599	.801128	7.904	1.979
5	709.402	.850892	7.048	1.764	5	631.440	.800332	7.918	1.983
6	707.945	.849999	7.063	1.768	6	630.286	.799538	7.933	1.987
7	706.493	.849108	7.077	1.771	7	629.136	.798745	7.947	1.990
8	705.048	.848219	7.092	1.775	8	627.991	.797953	7.962	1.994
9	703.609	.847331	7.106	1.778	9	626.849	.797163	7.976	1.998
10	702.175	2.846445	7.121	1.782	10	625.712	2.796374	7.991	2.001
11	700.748	2.845562	7.135	1.786	11	624.579	2.795587	8.005	2.005
12	699.326	.844679	7.150	1.790	12	623.450	.794801	8.020	2.008
13	697.910	.843799	7.164	1.793	13	622.325	.794017	8.034	2.012
14	696.499	.842921	7.179	1.797	14	621.203	.793234	8.049	2.016
15	695.095	.842044	7.193	1.801	15	620.087	.792453	8.063	2.019
16	693.696	.841169	7.208	1.804	16	618.974	.791673	8.078	2.023
17	692.302	.840296	7.222	1.807	17	617.865	.790894	8.092	2.026
18	690.914	.839424	7.237	1.811	18	616.760	.790117	8.107	2.030
19	689.532	.838555	7.251	1.815	19	615.660	.789341	8.121	2.034
20	688.156	2.837687	7.266	1.819	20	614.563	2.788566	8.136	2.037
21	686.785	2.836821	7.280	1.822	21	613.470	2.787793	8.150	2.041
22	685.419	.835956	7.295	1.826	22	612.380	.787021	8.165	2.045
23	684.059	.835093	7.309	1.829	23	611.295	.786251	8.179	2.048
24	682.704	.834232	7.324	1.833	24	610.214	.785482	8.194	2.052
25	681.354	.833373	7.338	1.837	25	609.136	.784714	8.208	2.056
26	680.010	.832515	7.353	1.840	26	608.062	.783948	8.223	2.060
27	678.671	.831660	7.367	1.844	27	606.992	.783183	8.237	2.063
28	677.338	.830805	7.382	1.848	28	605.926	.782420	8.252	2.066
29	676.008	.829953	7.396	1.851	29	604.864	.781657	8.266	2.070
30	674.686	2.829102	7.411	1.855	30	603.805	2.780897	8.281	2.074
31	673.369	2.828253	7.425	1.858	31	602.750	2.780137	8.295	2.077
32	672.056	.827405	7.440	1.862	32	601.698	.779379	8.310	2.081
33	670.748	.826560	7.454	1.866	33	600.651	.778622	8.324	2.084
34	669.446	.825715	7.469	1.869	34	599.607	.777867	8.339	2.088
35	668.148	.824873	7.483	1.873	35	598.567	.777112	8.353	2.092
36	666.856	.824032	7.498	1.877	36	597.530	.776360	8.368	2.096
37	665.568	.823193	7.512	1.880	37	596.497	.775608	8.382	2.099
38	664.286	.822355	7.527	1.884	38	595.467	.774858	8.397	2.103
39	663.008	.821519	7.541	1.888	39	594.441	.774109	8.411	2.106
40	661.736	2.820685	7.556	1.892	40	593.419	2.773361	8.426	2.110
41	660.468	2.819852	7.570	1.895	41	592.400	2.772615	8.440	2.113
42	659.205	.819021	7.585	1.899	42	591.384	.771870	8.455	2.117
43	657.947	.818191	7.599	1.903	43	590.372	.771126	8.469	2.121
44	656.694	.817363	7.614	1.906	44	589.364	.770383	8.484	2.125
45	655.446	.816537	7.628	1.910	45	588.359	.769642	8.498	2.128
46	654.202	.815712	7.643	1.914	46	587.357	.768902	8.513	2.132
47	652.963	.814889	7.657	1.918	47	586.359	.768164	8.527	2.135
48	651.729	.814067	7.672	1.921	48	585.364	.767426	8.542	2.139
49	650.499	.813247	7.686	1.924	49	584.373	.766690	8.556	2.142
50	649.274	2.812428	7.701	1.928	50	583.385	2.765955	8.571	2.146
51	648.054	2.811611	7.715	1.932	51	582.400	2.765221	8.585	2.150
52	646.838	.810796	7.730	1.935	52	581.419	.764489	8.600	2.154
53	645.627	.809982	7.744	1.939	53	580.441	.763758	8.614	2.158
54	644.420	.809169	7.759	1.943	54	579.466	.763028	8.629	2.161
55	643.218	.808358	7.773	1.946	55	578.494	.762299	8.643	2.165
56	642.021	.807549	7.788	1.950	56	577.526	.761572	8.658	2.168
57	640.828	.806741	7.802	1.953	57	576.561	.760845	8.672	2.172
58	639.639	.805935	7.817	1.957	58	575.599	.760120	8.687	2.175
59	638.455	.805130	7.831	1.961	59	574.641	.759397	8.701	2.17
60	637.275	2.804327	7.846	1.965	60	573.686	2.758674	8.716	2.

Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.
6° 0′	955.366	2.980170	5.234	1.309	7° 0′	819.020	2.913295	6.105	1.528
1	952.722	.978966	5.248	1.313	1	817.077	.912263	6.119	1.531
2	950.093	.977766	5.263	1.317	2	815.144	.911234	6.134	1.535
3	947.478	.976569	5.277	1.320	3	813.219	.910208	6.148	1.539
4	944.877	.975375	5.292	1.324	4	811.303	.909183	6.163	1.543
5	942.291	.974185	5.306	1.327	5	809.397	.908162	6.177	1.546
6	939.719	.972998	5.321	1.331	6	807.499	.907142	6.192	1.550
7	937.161	.971814	5.335	1.335	7	805.611	.906125	6.206	1.553
8	934.616	.970633	5.350	1.338	8	803.731	.905111	6.221	1.557
9	932.086	.969456	5.364	1.342	9	801.860	.904098	6.236	1.561
10	929.569	2.968282	5.379	1.346	10	799.997	2.903089	6.250	1.564
11	927.066	2.967111	5.393	1.349	11	798.144	2.902081	6.265	1.568
12	924.576	.965943	5.408	1.353	12	796.299	.901076	6.279	1.572
13	922.100	.964778	5.422	1.356	13	794.462	.900073	6.294	1.575
14	919.637	.963616	5.437	1.360	14	792.634	.899073	6.308	1.579
15	917.187	.962458	5.451	1.364	15	790.814	.898074	6.323	1.582
16	914.750	.961303	5.466	1.368	16	789.003	.897078	6.337	1.586
17	912.326	.960150	5.480	1.371	17	787.200	.896085	6.352	1.590
18	909.915	.959001	5.495	1.375	18	785.405	.895094	6.366	1.593
19	907.517	.957855	5.510	1.378	19	783.618	.894105	6.381	1.597
20	905.131	2.956711	5.524	1.382	20	781.840	2.893118	6.395	1.600
21	902.758	2.955571	5.539	1.386	21	780.069	2.892133	6.410	1.604
22	900.397	.954434	5.553	1.389	22	778.307	.891151	6.424	1.608
23	898.048	.953300	5.568	1.393	23	776.552	.890171	6.439	1.611
24	895.712	.952168	5.582	1.397	24	774.806	.889193	6.453	1.615
25	893.388	.951040	5.597	1.400	25	773.067	.888217	6.468	1.619
26	891.076	.949915	5.611	1.404	26	771.336	.887244	6.482	1.623
27	888.776	.948792	5.626	1.407	27	769.613	.886272	6.497	1.626
28	886.488	.947673	5.640	1.411	28	767.897	.885303	6.511	1.630
29	884.211	.946556	5.655	1.415	29	766.190	.884336	6.526	1.633
30	881.946	2.945442	5.669	1.418	30	764.489	2.883371	6.540	1.637
31	879.693	2.944331	5.684	1.422	31	762.797	2.882409	6.555	1.641
32	877.451	.943223	5.698	1.426	32	761.112	.881448	6.569	1.644
33	875.221	.942118	5.713	1.429	33	759.434	.880490	6.584	1.648
34	873.002	.941015	5.727	1.433	34	757.764	.879534	6.598	1.651
35	870.795	.939916	5.742	1.437	35	756.101	.878580	6.613	1.655
36	868.598	.938819	5.756	1.440	36	754.445	.877627	6.627	1.659
37	866.412	.937725	5.771	1.444	37	752.796	.876678	6.642	1.662
38	864.238	.936633	5.785	1.447	38	751.155	.875730	6.656	1.666
39	862.075	.935545	5.800	1.451	39	749.521	.874784	6.671	1.670
40	859.922	2.934459	5.814	1.455	40	747.894	2.873840	6.685	1.673
41	857.780	2.933376	5.829	1.458	41	746.274	2.872898	6.700	1.677
42	855.648	.932295	5.844	1.462	42	744.661	.871959	6.714	1.680
43	853.527	.931218	5.858	1.466	43	743.055	.871021	6.729	1.684
44	851.417	.930142	5.873	1.469	44	741.456	.870086	6.743	1.688
45	849.317	.929070	5.887	1.473	45	739.864	.869152	6.758	1.691
46	847.228	.928000	5.902	1.476	46	738.279	.868221	6.773	1.695
47	845.148	.926933	5.916	1.480	47	736.701	.867291	6.787	1.699
48	843.080	.925869	5.931	1.484	48	735.129	.866363	6.802	1.702
49	841.021	.924807	5.945	1.487	49	733.564	.865438	6.816	1.706
50	838.972	2.923747	5.960	1.491	50	732.005	2.864514	6.831	1.710
51	836.933	2.922691	5.974	1.495	51	730.454	2.863593	6.845	1.713
52	834.904	.921637	5.989	1.498	52	728.909	.862673	6.860	1.717
53	832.885	.920585	6.003	1.502	53	727.370	.861755	6.874	1.720
54	830.876	.919536	6.018	1.505	54	725.838	.860840	6.889	1.724
55	828.876	.918489	6.032	1.510	55	724.312	.859926	6.903	1.728
56	826.886	.917446	6.047	1.513	56	722.793	.859014	6.918	1.731
57	824.905	.916404	6.061	1.517	57	721.280	.858104	6.932	1.735
58	822.934	.915365	6.076	1.520	58	719.774	.857196	6.947	1.739
59	820.973	.914329	6.090	1.524	59	718.273	.856290	6.961	1.742
60	819.020	2.913295	6.105	1.528	60	716.779	2.855385	6.976	1.746

Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.
8° 0′	716.779	2.855385	6.976	1.746	9° 0′	637.275	2.804327	7.846	1.965
1	715.291	.854483	6.990	1.749	1	636.099	.803525	7.860	1.968
2	713.810	.853583	7.005	1.753	2	634.928	.802724	7.875	1.972
3	712.335	.852684	7.019	1.756	3	633.761	.801926	7.889	1.975
4	710.865	.851787	7.034	1.760	4	632.599	.801128	7.904	1.979
5	709.402	.850892	7.048	1.764	5	631.440	.800332	7.918	1.983
6	707.945	.849999	7.063	1.768	6	630.286	.799538	7.933	1.987
7	706.493	.849108	7.077	1.771	7	629.136	.798745	7.947	1.990
8	705.048	.848219	7.092	1.775	8	627.991	.797953	7.962	1.994
9	703.609	.847331	7.106	1.778	9	626.849	.797163	7 976	1.998
10	702.175	2.846445	7.121	1.782	10	625.712	2.796374	7.991	2.001
11	700.748	2.845562	7.135	1.786	11	624.579	2.795587	8.005	2.005
12	699.326	.844679	7.150	1.790	12	623.450	.794801	8.020	2.008
13	697.910	.843799	7.164	1.793	13	622.325	.794017	8.034	2.012
14	696.499	.842921	7.179	1.797	14	621.203	.793234	8.049	2.016
15	695.095	.842044	7.193	1.801	15	620.087	.792453	8.063	2.019
16	693.696	.841169	7.208	1.804	16	618.974	.791673	8.078	2.023
17	692.302	.840296	7.222	1.807	17	617.865	.790894	8.092	2.026
18	690.914	.839424	7.237	1.811	18	616.760	.790117	8.107	2.030
19	689.532	.838555	7.251	1.815	19	615.660	.789341	8.121	2.034
20	688.156	2.837687	7.266	1.819	20	614.563	2.788566	8.136	2.037
21	686.785	2.836821	7.280	1.822	21	613.470	2.787793	8.150	2.041
22	685.419	.835956	7.295	1.826	22	612.380	.787021	8.165	2.045
23	684.059	.835093	7.309	1.829	23	611.295	.786251	8.179	2.048
24	682.704	.834232	7.324	1.833	24	610.214	.785482	8.194	2.052
25	681.354	.833373	7.338	1.837	25	609.136	.784714	8.208	2.056
26	680.010	.832515	7.353	1.840	26	608.062	.783948	8.223	2.060
27	678.671	.831660	7.367	1.844	27	606.992	.783183	8.237	2.063
28	677.338	.830805	7.382	1.848	28	605.926	.782420	8.252	2.066
29	676.008	.829953	7.396	1.851	29	604.864	.781657	8.266	2.070
30	674.686	2.829102	7.411	1.855	30	603.805	2.780897	8.281	2.074
31	673.369	2.828253	7.425	1.858	31	602.750	2.780137	8.295	2.077
32	672.056	.827405	7.440	1.862	32	601.698	.779379	8.310	2.081
33	670.748	.826560	7.454	1.866	33	600.651	.778622	8.324	2.084
34	669.446	.825715	7.469	1.869	34	599.607	.777867	8.339	2.088
35	668.148	.824873	7.483	1.873	35	598.567	.777112	8.353	2.092
36	666.856	.824032	7.498	1.877	36	597.530	.776360	8.368	2.096
37	665.568	.823193	7.512	1.880	37	596.497	.775608	8.382	2.099
38	664.286	.822355	7.527	1.884	38	595.467	.774858	8.397	2.103
39	663.008	.821519	7.541	1.888	39	594.441	.774109	8.411	2.106
40	661.736	2.820685	7.556	1.892	40	593.419	2.773361	8.426	2.110
41	660.468	2.819852	7.570	1.895	41	592.400	2.772615	8.440	2.113
42	659.205	.819021	7.585	1.899	42	591.384	.771870	8.455	2.117
43	657.947	.818191	7.599	1.903	43	590.372	.771126	8.469	2.121
44	656.694	.817363	7.614	1.906	44	589.364	.770383	8.484	2.125
45	655.446	.816537	7.628	1.910	45	588.359	.769642	8.498	2.128
46	654.202	.815712	7.643	1.914	46	587.357	.768902	8.513	2.132
47	652.963	.814889	7.657	1.918	47	586.359	.768164	8.527	2.135
48	651.729	.814067	7.672	1.921	48	585.364	.767426	8.542	2.139
49	650.499	.813247	7.686	1.924	49	584.373	.766690	8.556	2.142
50	649.274	2.812428	7.701	1.928	50	583.385	2.765955	8.571	2.146
51	648.054	2.811611	7.715	1.932	51	582.400	2.765221	8.585	2.150
52	646.838	.810796	7.730	1.935	52	581.419	.764489	8.600	2.154
53	645.627	.809982	7.744	1.939	53	580.441	.763758	8.614	2.158
54	644.420	.809169	7.759	1.943	54	579.466	.763028	8.629	2.161
55	643.218	.808358	7.773	1.946	55	578.494	.762299	8.643	2.165
56	642.021	.807549	7.788	1.950	56	577.526	.761572	8.658	2.168
57	640.828	.806741	7.802	1.953	57	576.561	.760845	8.672	2.172
58	639.639	.805935	7.817	1.957	58	575.599	.760120	8.687	2.17
59	638.455	.805130	7.831	1.961	59	574.641	.759397	8.701	2.1
60	637.275	2.804327	7.846	1.965	60	573.686	2.758674	8.716	2.

Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.
18° 0′	319.623	2.504638	15.643	3.935
2	319.037	.503841	15.672	3.942
4	318.453	.503045	15.701	3.950
6	317.871	.502251	15.730	3.957
8	317.292	.501459	15.758	3.964
10	316.715	.500668	15.787	3.972
12	316.139	.499879	15.816	3.979
14	315.566	.499091	15.845	3.986
16	314.993	.498304	15.873	3.994
18	314.426	.497519	15.902	4.001
20	313.860	2.496736	15.931	4.008
22	313.295	.495953	15.959	4.016
24	312.732	.495173	15.988	4.023
26	312.172	.494393	16.017	4.030
28	311.613	.493616	16.046	4.038
30	311.056	.492839	16.074	4.045
32	310.502	.492064	16.103	4.052
34	309.949	.491291	16.132	4.060
36	309.399	.490518	16.160	4.067
38	308.850	.489748	16.189	4.074
40	308.303	2.488978	16.218	4.081
42	307.759	.488210	16.246	4.089
44	307.216	.487444	16.275	4.096
46	306.675	.486679	16.304	4.103
48	306.136	.485915	16.333	4.111
50	305.599	.485152	16.361	4.118
52	305.064	.484391	16.390	4.125
54	304.531	.483632	16.419	4.133
56	304.000	.482873	16.447	4.140
58	303.470	.482116	16.476	4.147
19° 0′	302.943	2.481361	16.505	4.155
2	302.417	.480607	16.533	4.162
4	301.893	.479854	16.562	4.169
6	301.371	.479102	16.591	4.177
8	300.851	.478352	16.620	4.184
10	300.333	.477603	16.648	4.191
12	299.816	.476855	16.677	4.199
14	299.302	.476109	16.706	4.206
16	298.789	.475364	16.734	4.213
18	298.278	.474621	16.763	4.221
20	297.768	2.473878	16.792	4.228
22	297.260	.473137	16.820	4.235
24	296.755	.472398	16.849	4.243
26	296.250	.471659	16.878	4.250
28	295.748	.470922	16.906	4.257
30	295.247	.470186	16.935	4.265
32	294.748	.469452	16.964	4.272
34	294.251	.468718	16.992	4.279
36	293.756	.467986	17.021	4.287
38	293.262	.467256	17.050	4.294
40	292.770	2.466526	17.078	4.301
42	292.279	.465798	17.107	4.308
44	291.790	.465071	17.136	4.316
46	291.303	.464345	17.164	4.323
48	290.818	.463621	17.193	4.330
50	290.334	.462897	17.222	4.338
52	289.851	.462175	17.250	4.345
54	289.371	.461455	17.279	4.352
56	*288.892*	.460735	17.308	4.360
58	*288.414*	.460017	17.336	4.367
60	*287.930*	2.459300	17.365	4.374

Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.
20° 0′	287.930	2.459300	17.365	4.374
10	285.583	.455733	17.508	4.411
20	283.267	.452195	17.651	4.448
30	280.988	.448688	17.794	4.484
40	278.746	.445209	17.937	4.521
50	276.541	.441759	18.081	4.558
21° 0′	274.370	2.438337	18.224	4.594
10	272.234	.434943	18.367	4.631
20	270.132	.431576	18.509	4.668
30	268.062	.428235	18.652	4.704
40	266.024	.424921	18.795	4.741
50	264.018	.421633	18.938	4.778
22° 0′	262.042	2.418371	19.081	4.814
10	260.098	.415134	19.224	4.851
20	258.180	.411922	19.366	4.888
30	256.292	.408734	19.509	4.925
40	254.431	.405571	19.652	4.961
50	252.599	.402431	19.794	4.998
23° 0′	250.793	2.399315	19.937	5.035
10	249.013	.396222	20.079	5.071
20	247.258	.393151	20.222	5.108
30	245.529	.390103	20.364	5.145
40	243.825	.387077	20.507	5.182
50	242.144	.384074	20.649	5.218
24° 0′	240.487	2.381091	20.791	5.255
10	238.853	.378130	20.933	5.292
20	237.241	.375190	21.076	5.329
30	235.652	.372270	21.218	5.366
40	234.084	.369371	21.360	5.402
50	232.537	.366492	21.502	5.439
25° 0′	231.011	2.363633	21.644	5.476
10	229.506	.360794	21.786	5.513
20	228.020	.357974	21.928	5.549
30	226.555	.355173	22.070	5.586
40	225.108	.352391	22.212	5.623
50	223.680	.349627	22.353	5.660
26° 0′	222.271	2.346882	22.495	5.697
10	220.879	.344155	22.637	5.734
20	219.506	.341446	22.778	5.770
30	218.150	.338755	22.920	5.807
40	216.811	.336081	23.062	5.844
50	215.489	.333424	23.203	5.881
27° 0′	214.183	2.330785	23.345	5.918
10	212.893	.328162	23.486	5.955
20	211.620	.325556	23.627	5.992
30	210.362	.322967	23.769	6.029
40	209.119	.320393	23.910	6.065
50	207.891	.317836	24.051	6.102
28° 0′	206.678	2.315295	24.192	6.139
10	205.480	.312769	24.333	6.176
20	204.296	.310259	24.474	6.213
30	203.125	.307764	24.615	6.250
40	201.969	.305285	24.756	6.287
50	200.826	.302820	24.897	6.324
29° 0′	199.696	2.300370	25.038	6.360
10	198.580	.297935	25.179	6.398
20	197.476	.295515	25.320	6.435
30	196.385	.293108	25.460	6.472
40	195.306	.290716	25.601	6.509
50	194.240	.288338	25.741	6.545
30° 0′	193.185	2.285974	25.882	6.583

Deg. D.	Radius. R.	Logarithm. log. R.	Tan. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Logarithm. log. R.	Tan. Off. t.	Mid. Ord. m.
14° 0′	410.275	2.613075	12.187	3.058	16° 0′	359.265	2.555415	13.917	3.496
2	409.306	.612048	12.216	3.065	2	358.523	.554517	13.946	3.504
4	408.341	.611023	12.245	3.073	4	357.784	.553621	13.975	3.511
6	407.380	.610000	12.274	3.080	6	357.048	.552727	14.004	3.518
8	406.424	.608980	12.302	3.087	8	356.315	.551834	14.033	3.526
10	405.473	.607962	12.331	3.095	10	355.585	.550944	14.061	3.533
12	404.526	.606946	12.360	3.102	12	354.859	.550055	14.090	3.540
14	403.583	.605933	12.389	3.109	14	354.135	.549169	14.119	3.547
16	402.645	.604923	12.418	3.117	16	353.414	.548284	14.148	3.555
18	401.712	.603914	12.447	3.124	18	352.696	.547401	14.177	3.562
20	400.782	2.602908	12.476	3.131	20	351.981	2.546519	14.205	3.569
22	399.857	.601905	12.504	3.138	22	351.269	.545640	14.234	3.577
24	398.937	.600904	12.533	3.146	24	350.560	.544762	14.263	3.584
26	398.020	.599905	12.562	3.153	26	349.854	.543887	14.292	3.591
28	397.108	.598908	12.591	3.160	28	349.150	.543013	14.320	3.599
30	396.200	.597914	12.620	3.168	30	348.450	.542140	14.349	3.606
32	395.296	.596922	12.649	3.175	32	347.752	.541270	14.378	3.613
34	394.396	.595933	12.678	3.182	34	347.057	.540401	14.407	3.621
36	393.501	.594945	12.706	3.190	36	346.365	.539535	14.436	3.628
38	392.609	.593960	12.735	3.197	38	345.676	.538670	14.464	3.635
40	391.722	2.592978	12.764	3.204	40	344.990	2.537806	14.493	3.643
42	390.838	.591997	12.793	3.211	42	344.306	.536945	14.522	3.650
44	389.959	.591019	12.822	3.219	44	343.625	.536085	14.551	3.657
46	389.084	.590043	12.851	3.226	46	342.947	.535227	14.580	3.664
48	388.212	.589069	12.880	3.233	48	342.271	.534370	14.608	3.672
50	387.345	.588097	12.908	3.241	50	341.598	.533516	14.637	3.679
52	386.481	.587128	12.937	3.248	52	340.928	.532663	14.666	3.686
54	385.621	.586161	12.966	3.255	54	340.260	.531811	14.695	3.694
56	384.765	.585196	12.995	3.263	56	339.595	.530962	14.723	3.701
58	383.913	.584233	13.024	3.270	58	338.933	.530114	14.752	3.708
15° 0	383.065	2.583272	13.053	3.277	17° 0	338.273	2.529268	14.781	3.716
2	382.220	.582314	13.081	3.284	2	337.616	.528424	14.810	3.723
4	381.380	.581358	13.110	3.292	4	336.962	.527581	14.838	3.730
6	380.543	.580403	13.139	3.299	6	336.310	.526740	14.867	3.738
8	379.709	.579451	13.168	3.306	8	335.660	.525900	14.896	3.745
10	378.880	.578501	13.197	3.314	10	335.013	.525062	14.925	3.752
12	378.054	.577553	13.226	3.321	12	334.369	.524226	14.954	3.760
14	377.231	.576608	13.254	3.328	14	333.727	.523392	14.982	3.767
16	376.412	.575664	13.283	3.336	16	333.088	.522559	15.011	3.774
18	375.597	.574722	13.312	3.343	18	332.451	.521728	15.040	3.781
20	374.786	2.573783	13.341	3.350	20	331.816	2.520898	15.069	3.789
22	373.977	.572845	13.370	3.358	22	331.184	.520070	15.097	3.796
24	373.173	.571910	13.399	3.365	24	330.555	.519244	15.126	3.803
26	372.372	.570977	13.427	3.372	26	329.928	.518419	15.155	3.811
28	371.574	.570045	13.456	3.379	28	329.303	.517596	15.184	3.818
30	370.780	.569116	13.485	3.387	30	328.689	.516774	15.212	3.825
32	369.989	.568189	13.514	3.394	32	328.061	.515954	15.241	3.833
34	369.202	.567264	13.543	3.401	34	327.443	.515136	15.270	3.840
36	368.418	.566340	13.572	3.409	36	326.828	.514319	15.299	3.847
38	367.637	.565419	13.600	3.416	38	326.215	.513504	15.327	3.855
40	366.859	2.564500	13.629	3.423	40	325.604	2.512690	15.356	3.862
42	366.085	.563582	13.658	3.431	42	324.996	.511878	15.385	3.869
44	365.315	.562667	13.687	3.438	44	324.390	.511067	15.414	3.877
46	364.547	.561754	13.716	3.445	46	323.786	.510258	15.442	3.884
48	363.783	.560843	13.744	3.452	48	323.184	.509451	15.471	3.891
50	363.022	.559933	13.773	3.460	50	322.585	.508645	15.500	3.899
52	362.264	.559026	13.802	3.467	52	321.989	.507840	15.529	3.906
54	361.510	.558120	13.831	3.474	54	321.394	.507037	15.557	3.913
56	360.758	.557216	13.860	3.482	56	320.801	.506236	15.586	3.920
58	360.010	.556315	13.889	3.489	58	320.211	.505436	15.615	3.928
60	359.265	2.555415	13.917	3.496	60	319.623	2.504638	15.643	3.93

Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Logarithm. log. R.	Tang. Off. t.	Mid. Ord. m.
18° 0′	319.623	2.504638	15.643	3.935	**20°** 0′	287.939	2.459300	17.365	4.374
2	319.037	.503841	15.672	3.942	10	285.583	.455733	17.508	4.411
4	318.453	.503045	15.701	3.950	20	283.267	.452195	17.651	4.448
6	317.871	.502251	15.730	3.957	30	280.988	.448688	17.794	4.484
8	317.292	.501459	15.758	3.964	40	278.746	.445209	17.937	4.521
10	316.715	.500668	15.787	3.972	50	276.541	.441759	18.081	4.558
12	316.139	.499879	15.816	3.979	**21°** 0′	274.370	2.438337	18.224	4.594
14	315.566	.499091	15.845	3.986	10	272.234	.434943	18.367	4.631
16	314.993	.498304	15.873	3.994	20	270.132	.431576	18.509	4.668
18	314.426	.497519	15.902	4.001	30	268.062	.428235	18.652	4.704
20	313.860	2.496736	15.931	4.008	40	266.024	.424921	18.795	4.741
22	313.295	.495953	15.959	4.016	50	264.018	.421633	18.938	4.778
24	312.732	.495173	15.988	4.023	**22°** 0′	262.042	2.418371	19.081	4.814
26	312.172	.494393	16.017	4.030	10	260.098	.415134	19.224	4.851
28	311.613	.493616	16.046	4.038	20	258.180	.411922	19.366	4.888
30	311.056	.492839	16.074	4.045	30	256.292	.408734	19.509	4.925
32	310.502	.492064	16.103	4.052	40	254.431	.405571	19.652	4.961
34	309.949	.491291	16.132	4.060	50	252.599	.402431	19.794	4.998
36	309.399	.490518	16.160	4.067	**23°** 0′	250.793	2.399315	19.937	5.035
38	308.850	.489748	16.189	4.074	10	249.013	.396222	20.079	5.071
40	308.303	2.488978	16.218	4.081	20	247.258	.393151	20.222	5.108
42	307.759	.488210	16.246	4.089	30	245.529	.390103	20.364	5.145
44	307.216	.487444	16.275	4.096	40	243.825	.387077	20.507	5.182
46	306.675	.486679	16.304	4.103	50	242.144	.384074	20.649	5.218
48	306.136	.485915	16.333	4.111	**24°** 0′	240.487	2.381091	20.791	5.255
50	305.599	.485152	16.361	4.118	10	238.853	.378130	20.933	5.292
52	305.064	.484391	16.390	4.125	20	237.241	.375190	21.076	5.329
54	304.531	.483632	16.419	4.133	30	235.652	.372270	21.218	5.366
56	304.000	.482873	16.447	4.140	40	234.084	.369371	21.360	5.402
58	303.470	.482116	16.476	4.147	50	232.537	.366492	21.502	5.439
19° 0′	302.943	2.481361	16.505	4.155	**25°** 0′	231.011	2.363633	21.644	5.476
2	302.417	.480607	16.533	4.162	10	229.506	.360794	21.786	5.513
4	301.893	.479854	16.562	4.169	20	228.020	.357974	21.928	5.549
6	301.371	.479102	16.591	4.177	30	226.555	.355173	22.070	5.586
8	300.851	.478352	16.620	4.184	40	225.108	.352391	22.212	5.623
10	300.333	.477603	16.648	4.191	50	223.680	.349627	22.353	5.660
12	299.816	.476855	16.677	4.199	**26°** 0′	222.271	2.346882	22.495	5.697
14	299.302	.476109	16.706	4.206	10	220.879	.344155	22.637	5.734
16	298.789	.475364	16.734	4.213	20	219.506	.341446	22.778	5.770
18	298.278	.474621	16.763	4.221	30	218.150	.338755	22.920	5.807
20	297.768	2.473878	16.792	4.228	40	216.811	.336081	23.062	5.844
22	297.260	.473137	16.820	4.235	50	215.480	.333424	23.203	5.881
24	296.755	.472398	16.849	4.243	**27°** 0′	214.183	2.330785	23.345	5.918
26	296.250	.471659	16.878	4.250	10	212.893	.328162	23.486	5.955
28	295.748	.470922	16.906	4.257	20	211.620	.325556	23.627	5.992
30	295.247	.470186	16.935	4.265	30	210.362	.322967	23.769	6.029
32	294.748	.469452	16.964	4.272	40	209.119	.320393	23.910	6.065
34	294.251	.468718	16.992	4.279	50	207.891	.317836	24.051	6.102
36	293.756	.467986	17.021	4.287	**28°** 0′	206.678	2.315295	24.192	6.139
38	293.262	.467256	17.050	4.294	10	205.480	.312769	24.333	6.176
40	292.770	2.466526	17.078	4.301	20	204.296	.310259	24.474	6.213
42	292.279	.465798	17.107	4.308	30	203.125	.307764	24.615	6.250
44	291.790	.465071	17.136	4.316	40	201.969	.305285	24.756	6.287
46	291.303	.464345	17.164	4.323	50	200.826	.302820	24.897	6.324
48	290.818	.463621	17.193	4.330	**29°** 0′	199.696	2.300370	25.038	6.360
50	290.334	.462897	17.222	4.338	10	198.580	.297935	25.179	6.398
52	289.851	.462175	17.250	4.345	20	197.476	.295515	25.320	6.435
54	289.371	.461455	17.279	4.352	30	196.385	.293108	25.460	6.472
56	288.892	.460735	17.308	4.360	40	195.306	.290716	25.601	6.509
58	288.414	.460017	17.336	4.367	50	194.240	.288338	25.741	6.545
60	287.939	2.459300	17.365	4.374	**30°** 0′	193.185	2.285974	25.882	6.583

Deg. D.	Radius. R.	Loga-rithm. log. R.	Tang. Off. t.	Mid. Ord. m.	Deg. D.	Radius. R.	Loga-rithm. log. R.	Tang. Off. t.	Mid. Ord. m.
30° 20′	191.111	2.281286	26.163	6.657	38°30′	151.657	2.180863	32.969	8.479
40	189.083	.276652	26.443	6.731	39° 0′	149.787	.175475	33.381	8.592
31° 0′	187.099	.272071	26.724	6.805	30	147.965	.170160	33.792	8.704
20	185.158	.267541	27.004	6.879	40° 0′	146.190	.164918	34.202	8.816
40	183.258	.263062	27.284	6.953	30	144.460	.159747	34.612	8.929
32° 0′	181.396	.258632	27.564	7.027	41° 0′	142.773	.154645	35.021	9.041
20	179.577	.254250	27.843	7.101	30	141.127	.149610	35.429	9.154
40	177.794	.249916	28.123	7.175	42° 0′	139.521	.144641	35.837	9.267
33° 0′	176.047	.245628	28.402	7.250	30	137.955	.139736	36.244	9.380
20	174.336	.241386	28.680	7.324	43° 0′	136.425	.134895	36.650	9.493
40	172.639	.237188	28.959	7.398	30	134.932	.130114	37.056	9.606
34° 0′	171.015	2.233035	29.237	7.473	44° 0′	133.473	2.125395	37.461	9.719
20	169.404	.228924	29.515	7.547	30	132.049	.120784	37.865	9.832
40	167.825	.224856	29.793	7.621	45° 0′	130.656	.116180	38.268	9.946
35° 0′	166.275	.220828	30.071	7.696	30	129.296	.111584	38.671	10.059
20	164.756	.216842	30.348	7.770	46° 0′	127.965	.107092	39.073	10.173
40	163.266	.212895	30.625	7.845	30	126.664	.102655	39.474	10.286
36° 0′	161.803	.208988	30.902	7.919	47° 0′	125.392	.098270	39.875	10.400
20	160.368	.205119	31.178	7.994	30	124.148	.093988	40.275	10.514
40	158.960	.201288	31.454	8.068	48° 0′	122.930	.089657	40.674	10.628
37° 0′	157.577	.197494	31.730	8.143	30	121.738	.085425	41.072	10.742
20	156.220	.193736	32.006	8.218	49° 0′	120.571	.081243	41.469	10.856
40	154.887	.190014	32.282	8.293	30	119.429	.077109	41.866	10.970
38° 0′	153.578	2.186328	32.557	8.367	50° 0′	118.310	2.073022	42.262	11.085

TABLE II.—CORRECTIONS FOR TANGENTS AND EXTERNALS

Ang △	For Tangents, add						Ang △	For Externals, add					
	5° Cur.	10° Cur.	15° Cur.	20° Cur.	25° Cur.	30° Cur.		5° Cur.	10° Cur.	15° Cur.	20° Cur.	25° Cur.	30° Cur.
10°	.03	.06	.09	.13	.16	.19	10°	.001	.003	.004	.006	.007	.008
20	.06	.13	.19	.26	.32	.39	20	.006	.011	.017	.022	.028	.034
30	.10	.19	.29	.39	.49	.59	30	.013	.025	.038	.051	.065	.078
40	.13	.26	.40	.53	.67	.80	40	.023	.046	.070	.093	.117	.141
50	.17	.34	.51	.68	.85	1.02	50	.037	.075	.116	.151	.189	.227
60	.21	.42	.63	.84	1.05	1.27	60	.056	.112	.168	.225	.283	.340
70	.25	.51	.76	1.02	1.28	1.54	70	.080	.159	.240	.321	.403	.485
80	.30	.61	.91	1.22	1.53	1.84	80	.110	.220	.332	.445	.558	.671
90	.36	.72	1.09	1.45	1.83	2.20	90	.149	.299	.450	.603	.756	.910
100	.43	.86	1.30	1.74	2.18	2.62	100	.200	.401	.604	.809	1.015	1.221
110	.51	1.03	1.56	2.08	2.61	3.14	110	.268	.536	.806	1.082	1.355	1.633
120	.62	1.25	1.93	2.52	3.16	3.81	120	.360	.721	1.086	1.456	1.825	2.197

Angle. Δ	Tangent. T.	External. E.	Angle. Δ	Tangent. T.	External. E.	Angle. Δ	Tangent. T.	External. E.
1°	50.00	.218	**11**	551.70	26.500	**21°**	1061.9	97.577
10	58.34	.297	10′	560.11	27.313	10′	1070.6	99.155
20	66.67	.388	20	568.53	28.137	20	1079.2	100.75
30	75.01	.491	30	576.95	28.974	30	1087.8	102.35
40	83.34	.606	40	585.36	29.824	40	1096.4	103.97
50	91.68	.733	50	593.79	30.686	50	1105.1	105.60
2	100.01	.873	**12**	602.21	31.561	**22**	1113.7	107.24
10	108.35	1.024	10	610.64	32.447	10	1122.4	108.90
20	116.68	1.188	20	619.07	33.347	20	1131.0	110.57
30	125.02	1.364	30	627.50	34.259	30	1139.7	112.25
40	133.36	1.552	40	635.93	35.183	40	1148.4	113.95
50	141.70	1.752	50	644.37	36.120	50	1157.0	115.66
3	150.04	1.964	**13**	652.81	37.070	**23**	1165.7	117.38
10	158.38	2.188	10	661.25	38.031	10	1174.4	119.12
20	166.72	2.425	20	669.70	39.006	20	1183.1	120.87
30	175.06	2.674	30	678.15	39.993	30	1191.8	122.63
40	183.40	2.934	40	686.60	40.992	40	1200.5	124.41
50	191.74	3.207	50	695.06	42.004	50	1209.2	126.20
4	200.08	3.492	**14**	703.51	43.029	**24**	1217.9	128.00
10	208.43	3.790	10	711.97	44.066	10	1226.6	129.83
20	216.77	4.099	20	720.44	45.116	20	1235.3	131.65
30	225.12	4.421	30	728.90	46.178	30	1244.0	133.50
40	233.47	4.755	40	737.37	47.253	40	1252.8	135.35
50	241.81	5.100	50	745.85	48.341	50	1261.5	137.23
5	250.16	5.459	**15**	754.32	49.441	**25**	1270.2	139.11
10	258.51	5.829	10	762.80	50.554	10	1279.0	141.01
20	266.86	6.211	20	771.29	51.679	20	1287.7	142.93
30	275.21	6.606	30	779.77	52.818	30	1296.5	144.85
40	283.57	7.013	40	788.26	53.969	40	1305.3	146.79
50	291.92	7.432	50	796.75	55.132	50	1314.0	148.75
6	300.28	7.863	**16**	805.25	56.309	**26**	1322.8	150.71
10	308.64	8.307	10	813.75	57.498	10	1331.6	152.69
20	316.99	8.762	20	822.25	58.699	20	1340.4	154.69
30	325.35	9.230	30	830.76	59.914	30	1349.2	156.70
40	333.71	9.710	40	839.27	61.141	40	1358.0	158.72
50	342.08	10.202	50	847.78	62.381	50	1366.8	160.76
7	350.44	10.707	**17**	856.30	63.634	**27**	1375.6	162.81
10	358.81	11.224	10	864.82	64.900	10	1384.4	164.86
20	367.17	11.753	20	873.35	66.178	20	1393.2	166.95
30	375.54	12.294	30	881.88	67.470	30	1402.0	169.04
40	383.91	12.847	40	890.41	68.774	40	1410.9	171.15
50	392.28	13.413	50	898.95	70.091	50	1419.7	173.27
8	400.66	13.991	**18**	907.49	71.421	**28**	1428.6	175.41
10	409.03	14.582	10	916.03	72.764	10	1437.4	177.55
20	417.41	15.184	20	924.58	74.119	20	1446.3	179.72
30	425.79	15.799	30	933.13	75.488	30	1455.1	181.89
40	434.17	16.426	40	941.69	76.869	40	1464.0	184.08
50	442.55	17.065	50	950.25	78.264	50	1472.9	186.29
9	450.93	17.717	**19**	958.81	79.671	**29**	1481.8	188.51
10	459.32	18.381	10	967.38	81.092	10	1490.7	190.74
20	467.71	19.058	20	975.96	82.525	20	1499.6	192.99
30	476.10	19.746	30	984.53	83.972	30	1508.5	195.25
40	484.49	20.447	40	993.12	85.431	40	1517.4	197.53
50	492.88	21.161	50	1001.7	86.904	50	1526.3	199.82
10	501.28	21.887	**20**	1010.3	88.389	**30**	1535.3	202.12
10	509.68	22.624	10	1018.9	89.888	10	1544.2	204.44
20	518.08	23.375	20	1027.5	91.399	20	1553.1	206.77
30	526.48	24.138	30	1036.1	92.924	30	1562.1	209.12
40	534.89	24.913	40	1044.7	94.462	40	1571.0	211.48
50	543.29	25.700	50	1053.3	96.013	50	1580.0	213.86

Angle. Δ	Tan-gent. T.	Exter-nal. E.	Angle. Δ	Tan-gent. T.	Exter-nal. E.	Angle. Δ	Tan-gent. T.	Exter-nal. E.
31°	1589.0	216.25	**41°**	2142.2	387.38	**51°**	2732.9	618.39
10	1598.0	218.66	10′	2151.7	390.71	10′	2743.1	622.81
20	1606.9	221.08	20	2161.2	394.06	20	2753.4	627.24
30	1615.9	223.51	30	2170.8	397.43	30	2763.7	631.69
40	1624.9	225.96	40	2180.3	400.82	40	2773.9	636.17
50	1633.9	228.42	50	2189.9	404.22	50	2784.2	640.66
32	1643.0	230.90	**42**	2199.4	407.64	**52**	2794.5	645.17
10	1652.0	233.39	10	2209.0	411.07	10	2804.9	649.70
20	1661.0	235.90	20	2218.6	414.52	20	2815.2	654.25
30	1670.0	238.43	30	2228.1	417.99	30	2825.6	658.83
40	1679.1	240.96	40	2237.7	421.48	40	2835.9	663.42
50	1688.1	243.52	50	2247.3	424.98	50	2846.3	668.03
33	1697.2	246.08	**43**	2257.0	428.50	**53**	2856.7	672.66
10	1706.3	248.66	10	2266.6	432.04	10	2867.1	677.32
20	1715.3	251.26	20	2276.2	435.59	20	2877.5	681.99
30	1724.4	253.87	30	2285.9	439.16	30	2888.0	686.68
40	1733.5	256.50	40	2295.6	442.75	40	2898.4	691.40
50	1742.6	259.14	50	2305.2	446.35	50	2908.9	696.13
34	1751.7	261.80	**44**	2314.9	449.98	**54**	2919.4	700.89
10	1760.8	264.47	10	2324.6	453.62	10	2929.9	705.66
20	1770.0	267.16	20	2334.3	457.27	20	2940.4	710.46
30	1779.1	269.86	30	2344.1	460.95	30	2951.0	715.28
40	1788.2	272.58	40	2353.8	464.64	40	2961.5	720.11
50	1797.4	275.31	50	2363.5	468.35	50	2972.1	724.97
35	1806.6	278.05	**45**	2373.3	472.08	**55**	2982.7	729.85
10	1815.7	280.82	10	2383.1	475.82	10	2993.3	734.76
20	1824.9	283.60	20	2392.8	479.59	20	3003.9	739.68
30	1834.1	286.39	30	2402.6	483.37	30	3014.5	744.62
40	1843.3	289.20	40	2412.4	487.17	40	3025.2	749.59
50	1852.5	292.02	50	2422.3	490.98	50	3035.8	754.57
36	1861.7	294.86	**46**	2432.1	494.82	**56**	3046.5	759.58
10	1870.9	297.72	10	2441.9	498.67	10	3057.2	764.61
20	1880.1	300.59	20	2451.8	502.54	20	3067.9	769.66
30	1889.4	303.47	30	2461.7	506.42	30	3078.7	774.73
40	1898.6	306.37	40	2471.5	510.33	40	3089.4	779.83
50	1907.9	309.29	50	2481.4	514.25	50	3100.2	784.94
37	1917.1	312.22	**47**	2491.3	518.20	**57**	3110.9	790.08
10	1926.4	315.17	10	2501.2	522.16	10	3121.7	795.24
20	1935.7	318.13	20	2511.2	526.13	20	3132.6	800.42
30	1945.0	321.11	30	2521.1	530.13	30	3143.4	805.62
40	1954.3	324.11	40	2531.1	534.15	40	3154.2	810.85
50	1963.6	327.12	50	2541.0	538.18	50	3165.1	816.10
38	1972.9	330.15	**48**	2551.0	542.23	**58**	3176.0	821.37
10	1982.2	333.19	10	2561.0	546.30	10	3186.9	826.66
20	1991.5	336.25	20	2571.0	550.39	20	3197.8	831.98
30	2000.9	339.32	30	2581.0	554.50	30	3208.8	837.31
40	2010.2	342.41	40	2591.1	558.63	40	3219.7	842.67
50	2019.6	345.52	50	2601.1	562.77	50	3230.7	848.06
39	2029.0	348.64	**49**	2611.2	566.94	**59**	3241.7	853.46
10	2038.4	351.78	10	2621.2	571.12	10	3252.7	858.89
20	2047.8	354.94	20	2631.3	575.32	20	3263.7	864.34
30	2057.2	358.11	30	2641.4	579.54	30	3274.8	869.82
40	2066.6	361.29	40	2651.5	583.78	40	3285.8	875.32
50	2076.0	364.50	50	2661.6	588.04	50	3296.9	880.84
40	2085.4	367.72	**50**	2671.8	592.32	**60**	3308.0	886.38
10	2094.9	370.95	10	2681.9	596.62	10	3319.1	891.95
20	2104.3	374.20	20	2692.1	600.93	20	3330.3	897.54
30	2113.8	377.47	30	2702.3	605.27	30	3341.4	903.15
40	2123.3	380.76	40	2712.5	609.62	40	3352.6	908.7
50	2132.7	384.06	50	2722.7	614.00	50	3363.8	914.

Angle. Δ	Tangent. T.	External. E.	Angle. Δ	Tangent. T.	External. E.	Angle. Δ	Tangent. T.	External. E.
61°	3375.0	920.14	71°	4086.9	1308.2	81°	4893.6	1805.3
10′	3386.3	925.85	10′	4099.5	1315.6	10′	4908.0	1814.7
20	3397.5	931.58	20	4112.1	1322.9	20	4922.5	1824.1
30	3408.8	937.34	30	4124.8	1330.3	30	4937.0	1833.6
40	3420.1	943.12	40	4137.4	1337.7	40	4951.5	1843.1
50	3431.4	948.92	50	4150.1	1345.1	50	4966.1	1852.6
62	3442.7	954.75	72	4162.8	1352.6	82	4980.7	1862.2
10	3454.1	960.60	10	4175.6	1360.1	10	4995.4	1871.8
20	3465.4	966.48	20	4188.4	1367.6	20	5010.0	1881.5
30	3476.8	972.38	30	4201.2	1375.2	30	5024.8	1891.2
40	3488.3	978.31	40	4214.0	1382.8	40	5039.5	1900.9
50	3499.7	984.27	50	4226.8	1390.4	50	5054.3	1910.7
63	3511.1	990.24	73	4239.7	1398.0	83	5069.2	1920.5
10	3522.6	996.24	10	4252.6	1405.7	10	5084.0	1930.4
20	3534.1	1002.3	20	4265.6	1413.5	20	5099.0	1940.3
30	3545.6	1008.3	30	4278.5	1421.2	30	5113.9	1950.3
40	3557.2	1014.4	40	4291.5	1429.0	40	5128.9	1960.2
50	3568.7	1020.5	50	4304.6	1436.8	50	5143.9	1970.3
64	3580.3	1026.6	74	4317.6	1444.6	84	5159.0	1980.4
10	3591.9	1032.8	10	4330.7	1452.5	10	5174.1	1990.5
20	3603.5	1039.0	20	4343.8	1460.4	20	5189.3	2000.6
30	3615.1	1045.2	30	4356.9	1468.4	30	5204.4	2010.8
40	3626.8	1051.4	40	4370.1	1476.4	40	5219.7	2021.1
50	3638.5	1057.7	50	4383.3	1484.4	50	5234.9	2031.4
65	3650.2	1063.9	75	4396.5	1492.4	85	5250.3	2041.7
10	3661.9	1070.2	10	4409.8	1500.5	10	5265.6	2052.1
20	3673.7	1076.6	20	4423.1	1508.6	20	5281.0	2062.5
30	3685.4	1082.9	30	4436.4	1516.7	30	5296.4	2073.0
40	3697.2	1089.3	40	4449.7	1524 9	40	5311.9	2083.5
50	3709.0	1095.7	50	4463.1	1533.1	50	5327.4	2094.1
66	3720.9	1102.2	76	4476.5	1541.4	86	5343.0	2104.7
10	3732.7	1108.6	10	4489.9	1549.7	10	5358.6	2115.3
20	3744.6	1115.1	20	4503.4	1558.0	20	5374.2	2126.0
30	3756.5	1121.7	30	4516.9	1566.3	30	5389.9	2136.7
40	3768.5	1128.2	40	4530.4	1574.7	40	5405.6	2147.5
50	3780.4	1134.8	50	4544.0	1583.1	50	5421.4	2158.4
67	3792.4	1141.4	77	4557.6	1591.6	87	5437.2	2169.2
10	3804.4	1148.0	10	4571.2	1600.1	10	5453.1	2180.2
20	3816.4	1154.7	20	4584.8	1608.6	20	5469.0	2191.1
30	3828.4	1161.3	30	4598.5	1617.1	30	5484.9	2202.2
40	3840.5	1168.1	40	4612.2	1625.7	40	5500.9	2213.2
50	3852.6	1174.8	50	4626.0	1634.4	50	5517.0	2224.3
68	3864.7	1181.6	78	4639.8	1643.0	88	5533.1	2235.5
10	3876.8	1188.4	10	4653.6	1651.7	10	5549.2	2246.7
20	3889.0	1195.2	20	4667.4	1660.5	20	5565.4	2258.0
30	3901.2	1202.0	30	4681.3	1669.2	30	5581.6	2269.3
40	3913.4	1208.9	40	4695.2	1678.1	40	5597.8	2280 6
50	3925.6	1215.8	50	4709.2	1686.9	50	5614.2	2292 0
69	3937.9	1222.7	79	4723.2	1695.8	89	5630.5	2303 5
10	3950.2	1229.7	10	4737.2	1704.7	10	5646.9	2315.0
20	3962.5	1236.7	20	4751.2	1713.7	20	5663.4	2326.6
30	3974.8	1243.7	30	4765.3	1722.7	30	5679.9	2338.2
40	3987.2	1250.8	40	4779.4	1731.7	40	5696.4	2349.8
50	3999.5	1257.9	50	4793.6	1740.8	50	5713.0	2361.5
70	4011.9	1265.0	80	4807.7	1749.9	90	5729.7	2373.3
10	4024.4	1272.1	10	4822.0	1759.0	10	5746.3	2385.1
20	4036.8	1279.3	20	4836.2	1768.2	20	5763.1	2397.0
30	4049.3	1286.5	30	4850.5	1777.4	30	5779.9	2408.9
40	4061.8	1293.6	40	4864.8	1786.7	40	5796.7	2420.9
50	4074.4	1300.9	50	4879.2	1796.0	50	5813.6	2433.1

Angle. Δ	Tangent. T.	External. E.	Angle. Δ	Tangent. T.	External. E.	Angle. Δ	Tangent. T.	External E.
91°	5830.5	2444.9	101°	6950.6	3278.1	111°	8336.7	4386.1
10′	5847.5	2457.1	10′	6971.3	3294.1	10′	8362.7	4407.6
20	5864.6	2469.3	20	6992.0	3310.1	20	8388.9	4429.2
30	5881.7	2481.5	30	7012.7	3326.1	30	8415.1	4450.9
40	5898.8	2493.8	40	7033.6	3342.3	40	8441.5	4472.7
50	5916.0	2506.1	50	7054.5	3358.5	50	8468.0	4494.6
92	5933.2	2518.5	102	7075.5	3374.9	112	8494.6	4516.6
10	5950.5	2531.0	10	7096.6	3391.2	10	8521.3	4538.8
20	5967.9	2543.5	20	7117.8	3407.7	20	8548.1	4561.1
30	5985.3	2556.0	30	7139.0	3424.3	30	8575.0	4583.4
40	6002.7	2568.6	40	7160.3	3440.9	40	8602.1	4606.0
50	6020.2	2581.3	50	7181.7	3457.6	50	8629.3	4628.6
93	6037.8	2594.0	103	7203.2	3474.4	113	8656.6	4651.3
10	6055.4	2606.8	10	7224.7	3491.3	10	8684.0	4674.2
20	6073.1	2619.7	20	7246.3	3508.2	20	8711.5	4697.2
30	6090.8	2632.6	30	7268.0	3525.2	30	8739.2	4720.3
40	6108.6	2645.5	40	7289.8	3542.4	40	8767.0	4743.6
50	6126.4	2658.5	50	7311.7	3559.6	50	8794.9	4766.9
94	6144.3	2671.6	104	7333.6	3576.8	114	8822.9	4790.4
10	6162.2	2684.7	10	7355.6	3594.2	10	8851.0	4814.1
20	6180.2	2697.9	20	7377.8	3611.7	20	8879.3	4837.8
30	6198.3	2711.2	30	7399.9	3629.2	30	8907.7	4861.7
40	6216.4	2724.5	40	7422.2	3646.9	40	8936.3	4885.7
50	6234.6	2737.9	50	7444.6	3664.5	50	8965 0	4909.9
95	6252.8	2751.3	105	7467.0	3682.3	115	8993.8	4934.1
10	6271.1	2764.8	10	7489.6	3700.2	10	9022.7	4958.6
20	6289.4	2778.3	20	7512.2	3718.2	20	9051.7	4983.1
30	6307.9	2792.0	30	7534.9	3736.2	30	9080.9	5007.8
40	6326.3	2805.6	40	7557.7	3754.4	40	9110.3	5032.6
50	6344.8	2819.4	50	7580.5	3772.6	50	9139.8	5057.6
96	6363.4	2833.2	106	7603.5	3791.0	116	9169.4	5082.7
10	6382.1	2847.0	10	7626.6	3809.4	10	9199.1	5107.9
20	6400.8	2861.0	20	7649.7	3827.9	20	9229.0	5133.3
30	6419.5	2875.0	30	7672.9	3846.5	30	9259.0	5158.8
40	6438.4	2889.0	40	7696.3	3865.2	40	9289.2	5184.5
50	6457.3	2903.1	50	7719.7	3884.0	50	9319.5	5210.3
97	6476.2	2917.3	107	7743.2	3902.9	117	9349.9	5236.2
10	6495.2	2931.6	10	7766.8	3921.9	10	9380.5	5262.3
20	6514.3	2945.9	20	7790.5	3940.9	20	9411.3	5288.6
30	6533.4	2960.3	30	7814.3	3960.1	30	9442.2	5315.0
40	6552.6	2974.7	40	7838.1	3979.4	40	9473.2	5341.5
50	6571.9	2989.2	50	7862.1	3998.7	50	9504.4	5368.2
98	6591.2	3003.8	108	7886.2	4018.2	118	9535.7	5395.1
10	6610.6	3018.4	10	7910.4	4037.8	10	9567.2	5422.1
20	6630.1	3033.1	20	7934.6	4057.4	20	9598.9	5449.2
30	6649.6	3047.9	30	7959.0	4077.2	30	9630.7	5476.5
40	6669.2	3062.8	40	7983.5	4097.1	40	9662.6	5504.0
50	6688.8	3077.7	50	8008.0	4117.0	50	9694.7	5531.7
99	6708.6	3092.7	109	8032.7	4137.1	119	9727.0	5559.4
10	6728.4	3107.7	10	8057.4	4157.3	10	9759.4	5587.4
20	6748.2	3122.9	20	8082.3	4177.5	20	9792.0	5615.5
30	6768.1	3138.1	30	8107.3	4197.9	30	9824.8	5643.8
40	6788.1	3153.3	40	8132.3	4218.4	40	9857.7	5672.3
50	6808.2	3168.7	50	8157.5	4239.0	50	9890.8	5700.9
100	6828.3	3184.1	110	8182.8	4259.7	120	9924.0	5729.7
10	6848.5	3199.6	10	8208.2	4280.5	10	9957.5	5758.6
20	6868.8	3215.1	20	8233.7	4301.4	20	9991.0	5787.7
30	6889.2	3230.8	30	8259.3	4322.4	30	10025.0	5817.0
40	6909.6	3246.5	40	8285.0	4343.6	40	10059.0	5846.
50	6930.1	3262.3	50	8310.8	4364.8	50	10093.0	587

Degree of Curve.	Actual Arc, One Station.	LONG CHORDS.				
		2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
0° 10′	100.000	200.000	299.999	399.998	499.996	599.993
20	.000	199.999	299.997	399.992	499.983	599.970
30	.000	199.998	299.992	399.981	499.962	599.933
40	.001	199.997	299.986	399.966	499.932	599.882
50	.001	199.995	299.979	399.947	499.894	599.815
1	100.001	199.992	299.970	399.924	499.848	599.733
10	.002	199.990	299.959	399.896	499.793	599.637
20	.002	199.986	299.946	399.865	499.729	599.526
30	.003	199.983	299.932	399.829	499.657	599.401
40	.003	199.979	299.915	399.789	499.577	599.260
50	.004	199.974	299.898	399.744	499.488	599.105
2	100.005	199.970	299.878	399.695	499.391	598.934
10	.006	199.964	299.857	399.643	499.285	598.750
20	.007	199.959	299.834	399.586	499.171	598.550
30	.008	199.952	299.810	399.524	499.049	598.336
40	.009	199.946	299.783	399.459	498.918	598.106
50	.010	199.939	299.756	399.389	498.778	597.862
3	100.011	199.931	299.726	399.315	498.630	597.604
10	.013	199.924	299.695	399.237	498.474	597.331
20	.014	199.915	299.662	399.154	498.309	597.043
30	.015	199.907	299.627	399.068	498.136	596.740
40	·017	199.898	299.591	398.977	497.955	596.423
50	.019	199.888	299.553	398.882	497.765	596.091
4	100.020	199.878	299.513	398.782	497.566	595.744
10	.022	199.868	299.471	398.679	497.360	595.383
20	.024	199.857	299.428	398.571	497.145	595.007
30	.026	199.846	299.383	398.459	496.921	594.617
40	.028	199.834	299.337	398.343	496.689	594.212
50	.030	199.822	299.289	398.223	496.449	593.792
5	100.032	199.810	299.239	398.099	496.201	593.358
10	.034	199.797	299.187	397.970	495.944	592.909
20	.036	199.783	299.134	397.837	495.678	592.446
30	.038	199.770	299.079	397.700	495.405	591.968
40	.041	199.756	299.023	397.559	495.123	591.476
50	.043	199.741	298.964	397.418	494.832	590.970
6	100.046	199.726	298.904	397.264	494.534	590.449
10	.048	199.710	298.843	397.110	494.227	589.913
20	.051	199.695	298.779	396.952	493.912	589.364
30	.054	199.678	298.714	396.790	493.588	588.800
40	.056	199.662	298.648	396.623	493.257	588.221
50	.059	199.644	298.579	396.453	492.917	587.628
7	100.062	199.627	298.509	396.278	492.568	587.021
10	.065	199.609	298.438	396.099	492.212	586.400
20	.068	199.591	298.364	395.916	491.847	585.765
30	.071	199.572	298.289	395.729	491.474	585.115
40	.075	199.553	298.212	395.538	491.093	584.451
50	.078	199.533	298.134	395.342	490.704	583.773
8	100.081	199.513	298.054	395.142	490.306	583.081
10	.085	199.492	297.972	394.938	489.900	582.375
20	.088	199.471	297.888	394.731	489.486	581.654
30	.092	199.450	297.803	394.518	489.064	580.920
40	.095	199.428	297.716	394.302	488.634	580.172
50	.099	199.406	297.628	394.082	488.196	579.409
9	100.103	199.383	297.538	393.857	487.749	578.633
10	.107	199.360	297.446	393.629	487.294	577.843
20	.111	199.337	297.352	393.396	486.832	577.039
30	.115	199.313	297.257	393.159	486.361	576.223
40	*.119*	199.289	297.160	392.918	485.882	575.390
50	*.123*	199.264	297.062	392.678	485.395	574.545
	100.127	199.239	296.962	392.424	484.900	573.686

Degree of Curve.	Long Chords.					
	7 Stations.	8 Stations.	9 Stations.	10 Stations.	11 Stations.	12 Stations.
0° 10	699.988	799.982	899.974	999.965	1099.95	1199.94
20	699.953	799.929	899.899	999.860	1099.81	1199.76
30	699.893	799.840	899.772	999.686	1099.58	1199.46
40	699.810	799.716	899.594	999.442	1099.25	1199.03
50	699.704	799.556	899.365	999.128	1098.84	1198.49
1	699.574	799.360	899.086	998.744	1098.33	1197.82
10	699.420	799.130	898.757	998.290	1097.72	1197.04
20	699.242	798.863	898.376	997.768	1097.02	1196.13
30	699.041	798.562	897.945	997.175	1096.23	1195.11
40	698.816	798.224	897.464	996.513	1095.35	1193.96
50	698.567	797.852	896.931	995.782	1094.38	1192.69
2	698.295	797.444	896.349	994.981	1093.31	1191.31
10	698.000	797 000	895.716	994.112	1092.15	1189.80
20	697.680	796.522	895.033	993.173	1090.90	1188.18
30	697.338	796.008	894.299	992.165	1089.56	1186.43
40	696.971	795.459	893.515	991.088	1088.12	1184.57
50	696.581	794.874	892.681	989.943	1086.60	1182.59
3	696.168	794.255	891.798	988.729	1084.98	1180.49
10	695.731	793.600	890.864	987.447	1083.28	1178.28
20	695.271	792.911	889.880	986.096	1081.48	1175.94
30	694.787	792.186	888.846	984.677	1079.59	1173.49
40	694.280	791.427	887.763	983.190	1077.61	1170.93
50	693.750	790.632	886.630	981.636	1075.54	1168.25
4	693.196	789.808	885.448	980.014	1073.38	1165.45
10	692.619	788.939	884.217	978.325	1071.14	1162.54
20	692.018	788.040	882.936	976.569	1068.81	1159.51
30	691.395	787.108	881.606	974.746	1066.38	1156.37
40	690.748	786.140	880.228	972.856	1063.87	1153.12
50	690.079	785.138	878.800	970.900	1061.27	1149.76
5	689.386	784.101	877.324	968.877	1058.59	1146.28
10	688.670	783.030	875.800	966.788	1055.81	1142.69
20	687.930	781.925	874.227	964.634	1052.95	1138.99
30	687.169	780.786	872.605	962.415	1050.01	1135.18
40	686.384	779.612	870.936	960.130	1046.97	1131.26
50	685.576	778.406	869.219	957.780	1043.86	1127.24
6	684.745	777.165	867.454	955.366	1040.66	1123.10
10	683.892	775.890	865.642	952.888	1037.37	1118.86
20	683.016	774.582	863.782	950.345	1034.01	1114.51
30	682.117	773.240	861.875	947.739	1030.55	1110.05
40	681.195	771.864	859.922	945.069	1027.02	1105.49
50	680.251	770.455	857.921	942.337	1023.40	1100.83
7	679.285	769.014	855.874	939.542	1019.70	1096.06
10	678.296	767.539	853.780	936.684	1015.93	1091.19
20	677.284	766.030	851.640	933.764	1012.07	1086.22
30	676.250	764.490	849.455	930.783	1008.13	1081.15
40	675.194	762.916	847.224	927.741	1004.11	1075.98
50	674.116	761.309	844.947	924.638	1000.01	1070.71
8	673.015	759.670	842.625	921.474	995.834	1065.34
10	671.892	757.999	840.258	918.250	991.580	1059.88
20	670.748	756.295	837.845	914.966	987.250	1054.32
30	669.581	754.560	835.389	911.623	982.844	1048.66
40	668.398	752.792	832.888	908.221	978.362	1042.91
50	667.182	750.993	830.342	904.761	973.806	1037.06
9	665.950	749.161	827.754	901.242	969.175	1031.13
10	664.697	747.299	825.121	897.667	964.471	1025.11
20	663.421	745.404	822.445	894.033	959.694	1018.99
30	662.124	743.479	819.726	890.343	954.844	1012.79
40	660.806	741.522	816.965	886.597	949.924	1006.49
50	659.466	739.535	814.160	882.795	944.933	1000.12
10	658.105	737.516	811.314	878.938	939.871	993.[illegible]

Degree of Curve.	Actual Arc, One Station.	Long Chords.				
		2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
10° 10′	100.131	199.213	296.860	392.171	484.397	572.813
20	.136	199.187	296.756	391.914	483.886	571.926
30	.140	199.161	296.651	391.652	483.367	571.027
40	.145	199.134	296.544	391.387	482.840	570.118
50	.149	199.107	296.436	391.117	482.305	569.186
11	100.154	199.079	296.325	390.843	481.762	568.245
10	.158	199.051	296.214	390.565	481.211	567.292
20	.163	199.023	296.100	390.284	480.653	566.324
30	.168	198.994	295.985	389.998	480.086	565.343
40	.173	198.964	295.868	389.708	479.511	564.349
50	.178	198.935	295.750	389.414	478.929	563.341
12	100.183	198.904	295.629	389.116	478.338	562.321
10	.188	198.874	295.508	388.814	477.740	561.287
20	.193	198.843	295.384	388.508	477.135	560.240
30	.199	198.811	295.259	388.197	476.521	559.180
40	.204	198.779	295.132	387.883	475.899	558.107
50	.209	198.747	295.004	387.565	475.270	557.020
13	100.215	198.714	294.874	387.243	474.633	555.921
10	.220	198.681	294.742	386.916	473.988	554.809
20	.226	198.648	294.609	386.586	473.336	553.684
30	.232	198.614	294.474	386.252	472.675	552.546
40	.237	198.579	294.337	385.914	472.007	551.395
50	.243	198.544	294.199	385.572	471.332	550.232
14	100.249	198.509	294.059	385.225	470.649	549.056
10	.255	198.474	293.918	384.875	469.958	547.867
20	.261	198.437	293.774	384.521	469.260	546.666
30	.267	198.401	293.629	384.163	468.554	545.452
40	.274	198.364	293.483	383.801	467.840	544.226
50	.280	198.327	293.335	383.435	467.119	542.987
15	100.286	198.289	293.185	383.065	466.390	541.736
10	.292	198.251	293.034	382.691	465.654	540.472
20	.299	198.212	292.881	382.313	464.911	539.196
30	.306	198.173	292.726	381.931	464.160	537.908
40	.312	198.134	292.570	381.546	463.401	536.608
50	.319	198.094	292.412	381.156	462.635	535.296
16	100.326	198.054	292.252	380.763	461.862	533.972
10	.333	198.013	292.091	380.365	461.081	532.635
20	.339	197.972	291.928	379.964	460.293	531.287
30	.346	197.930	291.764	379.559	459.498	529.927
40	.353	197.888	291.598	379.150	458.695	528.555
50	.361	197.846	291.430	378.737	457.886	527.171
17	100.368	197.803	291.261	378.320	457.069	525.776
10	.375	197.760	291.090	377.900	456.244	524.369
20	.382	197.716	290.918	377.475	455.413	522.950
30	.390	197.672	290.743	377.047	454.574	521.519
40	.397	197.628	290.568	376.615	453.728	520.078
50	.405	197.583	290.390	376.179	452.875	518.625
18	100.412	197.538	290.211	375.739	452.015	517.160
10	.420	197.492	290.031	375.295	451.147	515.685
20	.428	197.446	289.849	374.848	450.273	514.198
30	.436	197.399	289.665	374.397	449.392	512.699
40	.444	197.352	289.479	373.942	448.504	511.190
50	.452	197.305	289.292	373.483	447.608	509.670
19	100.460	197.256	289.104	373.021	446.706	508.139
10	.468	197.209	288.913	372.554	445.797	506.597
20	.476	197.160	288.722	372.084	444.881	505.043
30	.484	197.111	288.528	371.610	443.957	503.479
40	.493	197.062	288.333	371.133	443.028	501.905
	.501	197.012	288.137	370.652	442.091	500.320
	100.510	196.962	287.939	370.167	441.147	498.722

Degree of Curve.	7 Stations.	8 Stations.	9 Stations.	10 Stations.	11 Stations.	12 Stations.
	Long Chords.					
10° 10	656.723	735.467	808.426	875.035	934.741	987.105
20	655.320	733.387	805.495	871.058	929.542	980.473
30	653.895	731.277	802.524	867.038	924.276	973.760
40	652.450	729.137	799.512	862.963	918.943	966.967
50	650.983	726.967	796.458	858.836	913.544	960.093
11	649.496	724.767	793.364	854.656	908.080	953.141
10	647.989	722.537	790.230	850.425	902.550	946.112
20	646.460	720.278	787.056	846.140	896.957	939.007
30	644.911	717.990	783.843	841.808	891.303	931.828
40	643.342	715.672	780.590	837.424	885.586	924.575
50	641.752	713.325	777.298	832.990	879.807	917.250
12	640.142	710.950	773.968	828.507	873.968	909.854
10	638.512	708.546	770.600	823.974	868.070	902.389
20	636.862	706.113	767.193	819.394	862.113	894.855
30	635.191	703.653	763.749	814.766	856.099	887.254
40	633.501	701.164	760.268	810.092	850.028	879.588
50	631.792	698.647	756.749	805.370	843.900	871.857
13	630.062	696.103	753.194	800.602	837.718	864.063
10	628.313	693.531	749.603	795.790	831.482	856.208
20	626.544	690.932	745.976	790.932	825.192	848.293
30	624.756	688.306	742.313	786.030	818.850	840.318
40	622.949	685.653	738.616	781.085	812.457	832.286
50	621.123	682.974	734.883	776.096	806.013	824.198
14	619.278	680.268	731.116	771.066	799.520	816.056
10	617.413	677.535	727.315	765.998	792.979	807.860
20	615.530	674.777	723.480	760.879	786.389	799.612
30	613.628	671.993	719.612	755.725	779.753	791.313
40	611.706	669.183	715.711	750.531	773.072	782.966
50	609.769	666.348	711.777	745.297	766.345	774.571
15	607.812	663.488	707.811	740.024	759.575	766.130
10	605.836	660.603	703.814	734.714	752.763	
20	603.842	657.693	699.785	729.366	745.908	
30	601.831	654.758	695.725	723.982	739.014	
40	599.801	651.799	691.634	718.561	732.078	
50	597.753	648.817	687.513	713.105	725.104	
16	595.688	645.810	683.362	707.614	718.092	
10	593.605	642.780	679.182	702.088	711.043	
20	591.505	639.727	674.973	696.529	703.959	
30	589.388	636.650	670.735	690.938		
40	587.253	633.550	666.469	685.314		
50	585.101	630.428	662.175	679.659		
17	582.933	627.283	657.854	673.972		
10	580.747	624.117	653.506	668.256		
20	578.545	620.928	649.131	662.510		
30	576.326	617.717	644.730	656.735		
40	574.091	614.485	640.304	650.933		
50	571.839	611.232	635.852	645.103		
18	569.571	607.958	631.375	639.245		
10	567.287	604.664	626.874			
20	564.988	601.349	622.349			
30	562.673	598.013	617.801			
40	560.342	594.658	613.229			
50	557.996	591.283	608.635			
19	555.634	587.888	604.018			
10	553 257	584.475	599.379			
20	550.864	581.042	594.720			
30	548.457	577.591	590.039			
40	546.035	574.121	585.339			
50	543.599	*570.634*	580.618			
20	*541.147*	*567.128*	575.877			

Degree of Curve.	Actual Arc, One Station.	LONG CHORDS.				
		2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
21°	100.562	196.651	286.716	367.179	435.345	488.931
22	100.617	196.325	285.437	364.060	429.305	478.775
23	100.675	195.985	284.101	360.810	423.033	468.270
24	100.735	195.630	282.709	357.433	416.535	457.433
25	100.798	195.259	281.262	353.930	409.819	446.280
26	100.863	194.874	279.759	350.303	402.891	434.827
27	100.931	194.474	278.201	346.555	395.758	423.092
28	101.002	194.059	276.589	342.688	388.428	411.092
29	101.075	193.630	274.924	338.704	380.908	398.846
30	101.152	193.185	273.205	334.607	373.205	386.370
31	101.230	192.726	271.433	330.397	365.328	373.685
32	101.312	192.252	269.610	326.078	357.284	360.808
33	101.396	191.764	267.734	321.654	349.081	347.759
34	101.482	191.261	265.808	317.125	340.729	334.556
35	101.572	190.743	263.830	312.496	332.234	321.220
36	101.664	190.211	261.803	307.768	323.607	307.768
37	101.759	189.665	259.727	302.946	314.855	294.222
38	101.857	189.104	257.602	298.032	305.987	280.600
39	101.957	188.528	255.429	293.028	297.012	266.923
40	102.060	187.939	253.209	287.938	287.939	253.209
41	102.166	187.334	250.942	282.766	278.777	239.478
42	102.275	186.716	248.629	277.514	269.535	225.750
43	102.386	186.084	246.271	272.186	260.222	212.045
44	102.500	185.437	243.868	266.784	250.848	198.380
45	102.617	184.776	241.421	261.313	241.421	184.776
46	102.737	184.101	238.932	255.775	231.952	171.251
47	102.860	183.412	236.400	250.173	222.448	157.824
48	102.985	182.709	233.826	244.512	212.920	144.512
49	103.114	181.992	231.212	238.795	203.377	131.335
50	103.245	181.262	228.558	233.025	193.828	118.310

Deflection.		100.	200.	300.	400.	500.	600.	700.	800.	900.	1000.
	30'	0.87	1.75	2.62	3.49	4.36	5.24	6.11	6.98	7.85	8.73
1°		1.75	3.49	5.24	6.98	8.73	10.47	12.22	13.96	15.71	17.45
	30	2.62	5.24	7.85	10.47	13.09	15.71	18.33	20.94	23.56	26.18
2		3.49	6.98	10.47	13.96	17.45	20.94	24.42	27.92	31.41	34.90
	30	4.36	8.72	13.09	17.45	21.81	26.17	30.54	34.90	39.27	43.63
3		5.24	10.47	15.71	20.94	26.18	31.42	36.65	41.88	47.12	52.35
	30	6.11	12.22	18.32	24.43	30.54	36.65	42.75	48.86	54.97	61.08
4		6.98	13.96	20.94	27.92	34.90	41.88	48.86	55.84	62.82	69.80
	30	7.85	15.70	23.56	31.41	39.26	47.11	54.96	62.82	70.67	78.52
5		8.72	17.45	26.17	34.90	43.62	52.34	61.07	69.79	78.51	87.24
	30	9.60	19.19	28.79	38.38	47.98	57.57	67.17	76.76	86.36	95.96
6		10.47	20.93	31.40	41.87	52.34	62.80	73.27	83.74	94.20	104.67
	30	11.34	22.68	34.02	45.35	56.70	68.03	79.37	90.71	102.05	113.39
7		12.21	24.42	36.63	48.84	61.05	73.26	85.47	97.68	109.89	122.10
	30	13.08	26.16	39.24	52.32	65.40	78.49	91.57	104.64	117.73	130.81
8		13.95	27.90	41.85	55.80	69.76	83.71	97.66	111.61	125.56	139.51
	30	14.82	29.64	44.47	59.29	74.11	88.93	103.75	118.57	133.40	148.22
9		15.69	31.38	47.08	62.77	78.46	94.15	109.84	125.53	141.23	156.92
	30	16.56	33.12	49.68	66.25	82.81	99.37	115.93	132.49	149.05	165.62
10		17.43	34.86	52.29	69.72	87.16	104.59	122.02	139.45	156.88	174.31
	30	18.30	36.60	54.90	73.20	91.50	109.80	128.10	146.40	164.70	183.00
11		19.17	38.34	57.51	76.68	95.85	115.01	134.18	153.35	172.52	191.69
	30	20.04	40.08	60.11	80.15	100.19	120.23	140.26	160.30	180.34	200.38
12		20.91	41.81	62.72	83.62	104.53	125.43	146.34	167.25	188.15	209.06
	30	21.77	43.55	65.32	87.09	108.87	130.64	152.41	174.19	195.96	217.73
13		22.64	45.28	67.92	90.56	113.20	135.84	158.48	181.13	203.77	226.41
	30	23.51	47.01	70.52	94.03	117.54	141.04	164.55	188.06	211.57	235.07
14		24.37	48.75	73.12	97.50	121.87	146.24	170.62	194.99	219.36	243.74
	30	25.24	50.48	75.72	100.96	126.20	151.44	176.68	201.92	227.16	252.40
15		26.11	52.21	78.32	104.42	130.53	156.63	182.74	208.84	234.95	261.05
	30	26.97	53.94	80.91	107.88	134.85	161.82	188.79	215.76	242.73	269.70
16		27.83	55.67	83.50	111.34	139.17	167.01	194.84	222.68	250.51	278.35
	30	28.70	57.40	86.10	114.79	143.49	172.19	200.89	229.59	258.29	286.99
17		29.56	59.12	88.69	118.25	147.81	177.37	206.93	236.50	266.06	295.62
	30	30.42	60.85	91.27	121.70	152.12	182.55	212.97	243.40	273.82	304.25
18		31.29	62.57	93.86	125.15	156.43	187.72	219.01	250.30	281.58	312.87
	30	32.15	64.30	96.45	128.59	160.74	192.89	225.04	257.19	289.34	321.49
19		33.01	66.02	99.03	132.04	165.05	198.06	231.07	264.08	297.08	330.09
	30	33.87	67.74	101.61	135.48	169.35	203.22	237.09	270.96	304.83	338.70
20		34.73	69.46	104.19	138.92	173.65	208.38	243.11	277.84	312.57	347.30
	30	35.59	71.18	106.77	142.35	177.94	213.53	249.12	284.71	320.30	355.89
21		36.45	72.89	109.34	145.79	182.24	218.68	255.13	291.58	328.02	364.47
	30	37.30	74.61	111.91	149.22	186.52	223.83	261.13	298.44	335.74	373.05
22		38.16	76.32	114.49	152.65	190.81	228.97	267.13	305.29	343.46	381.62
	30	39.02	78.04	117.05	156.07	195.09	234.11	273.13	312.14	351.16	390.18
23		39.87	79.75	119.62	159.49	199.37	239.24	279.12	318.99	358.86	398.74
	30	40.73	81.46	122.19	162.91	203.64	244.37	285.10	325.83	366.56	407.28
24		41.58	83.16	124.75	166.33	207.91	249.49	291.08	332.66	374.24	415.82
	30	42.44	84.87	127.31	169.74	212.18	254.61	297.05	339.48	381.92	424.36
25		43.29	86.58	129.86	173.15	216.44	259.73	303.02	346.30	389.59	432.88
	30	44.14	88.28	132.42	176.56	220.70	264.84	308.98	353.12	397.26	441.39
26		44.99	89.98	134.97	179.96	224.95	269.94	314.93	359.92	404.91	449.90
	30	45.84	91.68	137.52	183.36	229.20	275.04	320.88	366.72	412.56	458.40
27		46.69	93.38	140.07	186.76	233.45	280.14	326.82	373.51	420.20	466.89
	30	47.54	95.07	142.61	190.15	237.69	285.22	332.76	380.30	427.83	475.37
28		48.38	96.77	145.15	193.54	241.92	290.31	338.69	387.08	435.46	483.84
	30	49.23	98.46	147.69	196.92	246.15	295.38	344.62	393.85	443.08	492.31
29		50.08	100.15	150.23	200.30	250.38	300.46	350.53	400.61	450.68	500.7
	30	50.92	101.84	152.76	203.68	254.60	305.52	356.44	407.36	458.28	509.
30		51.76	103.53	155.29	207.06	258.82	310.59	362.35	414.11	465.87	517

Degree of Curve.	1 Station.	2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
0° 10′	.036	.145	.327	.582	.909	1.309
20	.073	.291	.654	1.164	1.818	2.618
30	.109	.436	.982	1.745	2.727	3.926
40	.145	.582	1.309	2.327	3.636	5.235
50	.182	.727	1.636	2.909	4.545	6.544
1	.218	.873	1.963	3.490	5.453	7.852
10	.255	1.018	2.291	4.072	6.362	9.160
20	.291	1.164	2.618	4.654	7.270	10.468
30	.327	1.309	2.945	5.235	8.179	11.775
40	.364	1.454	3.272	5.816	9.087	13.082
50	.400	1.600	3.599	6.398	9.994	14.389.
2	.436	1.745	3.926	6.979	10.902	15.694
10	.473	1.891	4.253	7.560	11.809	17.000
20	.509	2.036	4.580	8.141	12.716	18.304
30	.545	2.181	4.907	8.722	13.623	19.608
40	.582	2.327	5.234	9.303	14.529	20.912
50	.618	2.472	5.561	9.883	15.435	22.214
3	.654	2.618	5.888	10.464	16.341	23.516
10	.691	2.763	6.215	11.044	17.246	24.817
20	.727	2.908	6.542	11.624	18.151	26.117
30	.763	3.054	6.868	12.204	19.055	27.416
40	.800	3.199	7.195	12.784	19.959	28.714
50	.836	3.345	7.522	13.363	20.863	30.012
4	.872	3.490	7.848	13.943	21.766	31.308
10	.909	3.635	8.175	14.522	22.668	32.603
20	.945	3.781	8.501	15.101	23.570	33.896
30	.982	3.926	8.828	15.680	24.471	35.189
40	1.018	4.071	9.154	16.258	25.372	36.480
50	1.054	4.217	9.480	16.837	26.272	37.770
5	1.091	4.362	9.807	17.415	27.171	39.059
10	1.127	4.507	10.133	17.992	28.070	40.346
20	1.164	4.653	10.459	18.570	28.968	41.631
30	1.200	4.798	10.785	19.147	29.866	42.916
40	1.237	4.943	11.111	19.724	30.762	44.198
50	1.273	5.088	11.436	20.301	31.658	45.479
6	1.309	5.234	11.762	20.877	32.553	46.759
10	1.346	5.379	12.088	21.453	33.448	48.037
20	1.382	5.524	12.413	22.029	34.341	49.313
30	1.418	5.669	12.739	22.604	35.234	50.587
40	1.455	5.814	13.064	23.179	36.126	51.860
50	1.491	5.960	13.389	23.754	37.017	53.130
7	1.528	6.105	13.715	24.328	37.907	54.399
10	1.564	6.250	14.040	24.902	38.796	55.666
20	1.600	6.395	14.365	25.476	39.684	56.931
30	1.637	6.540	14.689	26.049	40.571	58.193
40	1.673	6.685	15.014	26.622	41.458	59.454
50	1.710	6.831	15.339	27.195	42.343	60.712
8	1.746	6.976	15.663	27.767	43.227	61.969
10	1.782	7.121	15.988	28.338	44.110	63.223
20	1.819	7.266	16.312	28.910	44.992	64.475
30	1.855	7.411	16.636	29.481	45.873	65.724
40	1.892	7.556	16.960	30.051	46.753	66.972
50	1.928	7.701	17.284	30.621	47.632	68.216
9	1.965	7.846	17.608	31.190	48.510	69.459
10	2.001	7.991	17.932	31.759	49.386	70.699
20	2.037	8.136	18.255	32.328	50.261	71.936
30	*2.074*	8.281	18.578	32.896	51.135	73.171
40	*2.110*	8.426	18.902	33.464	52.008	74 403
50	*2.147*	8.571	19.225	34.031	52.880	75.[illegible]
	2.183	8.716	19.548	34.597	53.750	76.859

Degree of Curve.		7 Stations.	8 Stations.	9 Stations.	10 Stations.	11 Stations.	12 Stations.
0°	10′	1.782	2.327	2.945	3.636	4.400	5.236
	20	3.563	4.654	5.890	7.272	8.799	10.471
	30	5.345	6.981	8.835	10.907	13.197	15.704
	40	7.126	9.307	11.778	14.540	17.593	20.936
	50	8.907	11.632	14.721	18.173	21.987	26.164
1		10.687	13.957	17.663	21.803	26.378	31.388
	10	12.467	16.281	20.603	25.431	30.766	36.607
	20	14.246	18.604	23.541	29.057	35.150	41.821
	30	16.024	20.925	26.477	32.679	39.530	47.028
	40	17.803	23.246	29.411	36.298	43.905	52.229
	50	19.579	25.564	32.343	39.914	48.274	57.422
2		21.355	27.881	35.272	43.525	52.637	62.606
	10	23.130	30.197	38.198	47.131	56.993	67.780
	20	24.903	32.510	41.121	50.733	61.343	72.945
	30	26.676	34.821	44.040	54.330	65.684	78.098
	40	28.447	37.130	46.956	57.921	70.018	83.240
	50	30.216	39.436	49.868	61.506	74.342	88.370
3		31.984	41.740	52.776	65.084	78.657	93.486
	10	33.751	44.041	55.679	68.656	82.963	98.588
	20	35.516	46.339	58.577	72.221	87.258	103.675
	30	37.279	48.634	61.471	75.778	91.542	108.747
	40	39.040	50.926	64.360	79.328	95.814	113.803
	50	40.800	53.215	67.243	82.869	100.075	118.841
4		42.557	55.500	70.121	86.402	104.323	123.862
	10	44.312	57.781	72.992	89.925	108.558	128.864
	20	46.065	60.059	75.858	93.440	112.779	133.847
	30	47.816	62.333	78.717	96.945	116.986	138.810
	40	49.564	64.602	81.570	100.439	121.178	143.753
	50	51.310	66.868	84.416	103.924	125.356	148.674
5		53.053	69.129	87.255	107.397	129.517	153.572
	10	54.794	71.386	90.087	110.860	133.663	158.448
	20	56.532	73.638	92.911	114.311	137.791	163.300
	30	58.267	75.885	95.728	117.751	141.903	168.128
	40	59.999	78.127	98.536	121.178	145.997	172.931
	50	61.729	80.364	101.337	124.593	150.072	177.708
6		63.455	82.596	104.129	127.995	154.129	182.459
	10	65.178	84.822	106.912	131.384	158.166	187.182
	20	66.898	87.043	109.686	134.759	162.184	191.878
	30	68.615	89.258	112.452	138.120	166.182	196.545
	40	70.328	91.468	115.208	141.468	170.159	201.183
	50	72.037	93.671	117.954	144.800	174.114	205.792
7		73.744	95.868	120.691	148.118	178.048	210.370
	10	75.446	98.059	123.417	151.421	181.960	214.916
	20	77.145	100.244	126.134	154.708	185.850	219.431
	30	78.840	102.422	128.840	157.979	189.716	223.914
	40	80.531	104.594	131.535	161.234	193.559	228.363
	50	82.218	106.758	134.219	164.473	197.377	232.779
8		83.901	108.916	136.893	167.695	201.171	237.160
	10	85.580	111.067	139.555	170.899	204.941	241.507
	20	87.254	113.210	142.205	174.086	208.685	245.818
	30	88.924	115.346	144.844	177.255	212.403	250.093
	40	90.590	117.475	147.470	180.407	216.095	254.331
	50	92.252	119.596	150.085	183.539	219.760	258.531
9		93.909	121.709	152.687	186.653	223.398	262.604
	10	95.561	123.814	155.277	189.748	227.008	266.818
	20	97.208	125.911	157.854	192.824	230.591	270.904
	30	98.851	128.000	160.417	195.880	234.145	274.949
	40	100.489	130.081	162.968	198.910	237.670	278.955
	50	*102.122*	*132.153*	165.505	201.932	241.167	282.919
10		*103.750*	*134.217*	168.029	204.928	244.633	286.84

Degree of Curve.	1 Station.	2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
10° 10′	2.219	8.860	19.870	35.164	54.619	78.083
20	2.256	9.005	20.193	35.729	55.486	79.305
30	2.293	9.150	20.516	36.294	56.353	80.523
40	2.329	9.295	20.838	36.859	57.218	81.739
50	2.365	9.440	21.160	37.423	58.081	82.951
11	2.402	9.585	21.483	37.986	58.943	84.161
10	2.438	9.729	21.804	38.549	59.804	85.368
20	2.475	9.874	22.126	39.111	60.663	86.571
30	2.511	10.019	22.448	39.673	61.521	87.772
40	2.547	10.164	22.769	40.234	62.377	88.969
50	2.584	10.308	23.090	40.795	63.232	90.164
12	2.620	10.453	23.412	41.355	64.085	91.355
10	2.657	10.597	23.732	41.914	64.937	92.542
20	2.693	10.742	24.053	42.473	65.787	93.727
30	2.730	10.887	24.374	43.031	66.636	94.908
40	2.766	11.031	24.694	43.588	67.482	96.086
50	2.803	11.176	25.014	44.145	68.328	97.260
13	2.839	11.320	25.334	44.701	69.171	98.431
10	2.876	11.465	25.654	45.256	70.013	99.598
20	2.912	11.609	25.974	45.811	70.854	100.762
30	2.949	11.754	26.293	46.365	71.692	101.922
40	2.985	11.898	26.612	46.919	72.529	103.079
50	3.022	12.043	26.931	47.472	73.364	104.232
14	3.058	12.187	27.250	48.024	74.197	105.381
10	3.095	12.331	27.569	48.575	75.029	106.527
20	3.131	12.476	27.887	49.126	75.859	107.669
30	3.168	12.620	28.206	49.676	76.687	108.807
40	3.204	12.764	28.524	50.225	77.513	109.941
50	3.241	12.908	28.841	50.773	78.337	111.071
15	3.277	13.053	29.159	51.321	79.159	112.197
10	3.314	13.197	29.476	51.868	79.979	113.319
20	3.350	13.341	29.794	52.414	80.798	114.438
30	3.387	13.485	30.111	52.959	81.614	115.552
40	3.423	13.629	30.427	53.504	82.429	116.662
50	3.460	13.773	30.744	54.048	83.241	117.768
16	3.496	13.917	31.060	54.591	84.052	118.870
10	3.533	14.061	31.376	55.133	84.861	119.967
20	3.569	14.205	31.692	55.675	85.667	121.061
30	3.606	14.349	32.008	56.215	86.471	122.150
40	3.643	14.493	32.323	56.755	87.274	123.235
50	3.679	14.637	32.638	57.294	88.074	124.315
17	3.716	14.781	32.953	57.832	88.872	125.391
10	3.752	14.925	33.267	58.369	89.668	126.463
20	3.789	15.069	33.582	58.906	90.462	127.530
30	3.825	15.212	33.896	59.441	91.254	128.593
40	3.862	15.356	34.210	59.976	92.043	129.651
50	3.899	15.500	34.523	60.510	92.830	130.704
18	3.935	15.643	34.837	61.042	93.616	131.753
10	3.972	15.787	35.150	61.574	94.398	132.797
20	4.008	15.931	35.463	62.106	95.179	133.837
30	4.045	16.074	35.775	62.636	95.957	134.872
40	4.081	16 218	36.088	63.165	96.733	135.902
50	4.118	16.361	36.400	63.693	97.506	136.928
19	4.155	16.505	36.712	64.221	98 278	137.948
10	4.191	16.648	37.023	64.747	99.047	138.964
20	4.228	16.792	37.334	65.273	99.813	139.975
30	4.265	16 935	37.645	65.797	100.577	140.981
40	4.301	17.078	37.956	66.321	101.339	141.982
	4.338	17.222	38.266	66.843	102.098	142.978
	4.374	17.365	38.576	67.365	102.855	[illegible]

Degree of Curve.	1 Station.	2 Stations.	3 Stations.	4 Stations.	5 Stations.	6 Stations.
21°	4.594	18.224	40.431	70.473	107.344	149.809
22	4.814	19.081	42.275	73.545	111.741	155.460
23	5.035	19.937	44.108	76.577	116.042	160.917
24	5.255	20.791	45.929	79.570	120.243	166.172
25	5.476	21.644	47.738	82.520	124.342	171.221
26	5.697	22.495	49.534	85.427	128.335	176.058
27	5.918	23.345	51.317	88.289	132.219	180.677
28	6.139	24.192	53.086	91.105	135.990	185.075
29	6.360	25.038	54.842	93.873	139.647	189.245
30	6.583	25.882	56.583	96.593	143.185	193.185
31°	6.805	26.724	58.309	99.261	146.603	
32	7.027	27.564	60.019	101.878	149.898	
33	7.250	28.402	61.714	104.442	153.068	
34	7.473	29.237	63.392	106.952	156.110	
35	7.696	30.071	65.053	109.406	159.023	
36	7.919	30.903	66.698	111.803	161.803	
37	8.143	31.730	68.325	114.143		
38	8.367	32.557	69.933	116.424		
39	8.592	33.381	71.524	118.645		
40	8.816	34.203	73.095	120.805		
41°	9.041	35.021	74.647	122.902		
42	9.267	35.837	76.180	124.937		
43	9.493	36.650	77.693	126.909		
44	9.719	37.461	79.185	128.815		
45	9.946	38.268	80.656	130.656		
46	10.173	39.073	82.107			
47	10.400	39.875	83.535			
48	10.628	40.674	84.942			
49	10.856	41.469	86.327			
50°	11.085	42.262	87.689			

CORRECTIONS FOR SUBCHORD LENGTHS

D	50	25	20	10	D	50	25	20	10
3°	.004	.003	.002	.001	27°	.349	.218	.179	.092
4	.008	.005	.004	.002	28	.376	.235	.192	.099
5	.012	.008	.006	.003	29	.403	.252	.206	.106
6	.017	.011	.009	.005	30°	.431	.270	.221	.114
7	.023	.015	.012	.006	31	.461	.288	.236	.122
8	.030	.019	.016	.008	32	.491	.307	.252	.130
9	.039	.024	.020	.010	33	.523	.327	.268	.138
10°	.048	.030	.024	.013	34	.555	.347	.285	.147
11	.058	.036	.030	.015	35	.589	.368	.302	.156
12	.069	.043	.035	.018	36	.623	.390	.320	.165
13	.081	.050	.041	.021	37	.659	.412	.338	.174
14	.093	.058	.048	.025	38	.695	.435	.356	.184
15	.107	.067	.055	.028	39	.733	.458	.376	.194
16	.122	.076	.063	.032	40°	.771	.483	.396	.204
17	.138	.066	.071	.036	41	.811	.507	.416	.214
18	.155	.097	.079	.041	42	.851	.533	.437	.225
19	.172	.108	.088	.045	43	.893	.559	.458	.236
20°	.191	.119	.098	.050	44	.936	.586	.480	.248
21	.211	.132	.108	.056	45	.980	.613	.502	.259
22	.231	.144	.118	.061	46	1.024	.641	.525	.271
23	.253	.158	.130	.067	47	1.070	.670	.549	.283
24	.275	.172	.141	.073	48	1.117	.699	.573	[illegible]
25	.299	.187	.153	.079	49	1.165	.729	.598	
26°	.323	.202	.166	.085	50°	1.214	.760	[illegible]	

TABLE VII.—COEFFICIENTS FOR VALVOID ARCS

I.—Ratio of $u = \frac{l}{\Delta}$.

L	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
300	.3518	.3516	.3514	.3510	.3506	.3500	.3493	.3485	.3476	.3466	.3455	.3444
400	.3437	.3436	.3433	.3430	.3426	.3421	.3415	.3408	.3399	.3390	.3380	.3368
500	.3400	.3398	.3396	.3393	.3389	.3383	.3379	.3372	.3364	.3356	.3345	3335
600	.3379	.3378	.3376	.3373	.3369	.3365	.3359	.3353	.3345	.3337	.3327	.3317
700	.3367	.3366	.3364	.3361	.3357	.3353	.3347	.3341	.3334	.3326	.3316	.3306
800	.3359	.3358	.3356	.3353	.3349	.3345	.3340	.3333	.3326	.3318	.3309	.3299
900	.3353	.3352	.3350	.3348	.3344	.3340	.3334	.3328	.3321	.3313	.3304	.3294
1000	.3350	.3348	.3346	.3344	.3340	.3336	.3331	.3324	.3317	.3310	.3301	.3291
1200	.3345	.3343	.3341	.3339	.3336	.3331	.3326	.3320	.3313	.3305	.3296	.3286
1500	.3340	.3339	.3337	.3335	.3331	.3327	.3322	.3316	.3309	.3301	.3292	.3283
2000	.3337	.3336	.2333	.3331	.3328	.3324	.3319	.3313	.3306	.3298	.3289	.3280

II.—Ratio of $v = \frac{r}{L}$.

L	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
300	.7706	.7683	.7643	.7588	.7518	.7432	.7332	.7218	.7090	.6949	.6795	6630
400	.7611	.7588	.7549	.7495	.7425	.7341	.7243	.7130	.7004	.6865	.6714	6551
500	.7568	.7545	.7506	.7452	.7384	.7300	.7202	.7091	.6966	.6828	.6678	.6516
600	.7545	.7522	.7483	.7430	.7361	.7278	.7181	.7070	.6946	.6808	.6659	6498
700	.7531	.7508	.7469	.7416	.7348	.7265	.7168	.7057	.6933	.6797	.6648	6487
800	.7522	.7499	.7461	.7407	.7339	.7257	.7160	.7049	.6926	.6789	.6640	.6480
900	.7516	.7492	.7454	.7401	.7333	.7251	.7154	.7044	.6920	.6784	.6635	.6475
1000	.7512	.7489	.7450	.7397	.7329	.7247	.7150	.7040	.6917	.6780	.6632	.6472
1200	.7505	.7483	.7444	.7391	.7324	.7241	.7145	.7035	.6912	.6775	.6627	.6468
1500	.7501	.7478	.7440	.7387	.7319	.7237	.7141	.7031	.6908	.6772	.6624	.6464
2000	.7497	.7474	.7436	.7383	.7316	.7234	.7137	.7028	.6904	.6769	.6621	.6461

III.—Ratio of $l_1 = \frac{l}{\Delta' - \Delta''}$ = Length of Valvoid Arc corresponding to a Change of One Degree in the Angle Δ.

L	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
300	2.62	2.61	2.60	2.59	2.57	2.55	2.52	2.49	2.46	2.42	2.38	2.34
400	3.49	3.48	3.46	3.44	3.42	3.38	3.35	3.30	3.25	3.20	3.14	3.08
500	4.36	4.35	4.33	4.30	4.26	4.22	4.17	4.11	4.05	3.98	3.90	3.81
600	5.23	5.22	5.19	5.16	5.11	5.06	4.99	4.92	4.84	4.75	4.65	4.55
700	6.10	6.09	6.06	6.02	5.96	5.90	5.83	5.74	5.65	5.54	5.43	5.31
800	6.97	6.95	6.92	6.87	6.82	6.74	6.66	6.56	6.45	6.33	6.20	6.06
900	7.85	7.82	7.79	7.73	7.67	7.59	7.49	7.38	7.26	7.13	6.98	6.82
1000	8.72	8.69	8.65	8.59	8.52	8.43	8.32	8.20	8.07	7.92	7.75	7.58
1100	9.59	9.56	9.52	9.45	9.37	9.27	9.16	9.02	8.87	8.71	8.53	8.34
1200	10.46	10.43	10.38	10.31	10.22	10.11	9.99	9.84	9.68	9.50	9.31	9.09
1300	11.33	11.30	11.25	11.17	11.07	10.96	10.82	10.66	10.49	10.29	10.08	9.85
1400	12.21	12.17	12.11	12.03	11.93	11.80	11.65	11.48	11.29	11.08	10.86	10.61
1500	13.08	13.04	12.98	12.89	12.78	12.64	12.48	12.30	12.10	11.88	11.63	11.37
1600	13.95	13.91	13.84	13.75	13.63	13.49	13.32	13.12	12.91	12.67	12.41	12.13
[illegible]	14.82	14.78	14.71	14.61	14.48	14.33	14.15	13.94	13.71	13.46	13.18	12.88
	15.69	15.65	15.57	15.47	15.33	15.17	14.98	14.76	14.52	14.25	13.96	13.64
	6.57	16.52	16.44	16.33	16.19	16.01	15.81	15.58	15.33	15.04	14.73	14.40
	7.44	17.39	17.30	17.19	17.04	16.86	16.65	16.40	16.13	15.88	15.51	15.1[illegible]

TABLE VIII.—MIDDLE ORDINATES FOR RAILS

D	Length of Rail-Chord.												D
	60	45	33	32	30	28	26	24	22	20	18	16	
1°	.078	.043	.024	.022	.020	.017	.015	.013	.011	.009	.007	.006	1°
2	.157	.088	.047	.045	.039	.034	.030	.025	.021	.017	.014	.011	2
3	.235	.132	.070	.067	.059	.051	.044	.038	.032	.026	.021	.017	3
4	.314	.176	.094	.089	.079	.068	.059	.050	.042	.035	.028	.022	4
5	.391	.221	.118	.112	.098	.086	.074	.063	.053	.044	.035	.028	5
6	.471	.264	.143	.134	.118	.103	.088	.075	.063	.052	.042	.034	6
7	.550	.309	.166	.156	.137	.120	.103	.088	.074	.061	.049	.039	7
8	.628	.353	.190	.179	.157	.137	.118	.100	.084	.070	.057	.045	8
9	.706	.397	.214	.201	.177	.154	.133	.113	.095	.078	.064	.050	9
10	.785	.441	.237	.223	.196	.171	.147	.126	.105	.087	.071	.056	10
11	.863	.485	.261	.245	.216	.188	.162	.138	.116	.096	.078	.061	11
12	.942	.529	.285	.268	.235	.205	.177	.151	.127	.105	.085	.067	12
14	1.098	.617	.332	.312	.274	.238	.206	.175	.147	.122	.099	.078	14
16	1.255	.705	.379	.356	.313	.273	.235	.200	.168	.139	.113	.089	16
18	1.411	.793	.426	.400	.352	.307	.264	.225	.189	.156	.127	.100	18
20	1.567	.880	.473	.445	.391	.340	.293	.250	.210	.174	.141	.111	20
24	1.878	1.055	.567	.531	.467	.407	.351	.299	.251	.207	.168	.133	24
28	2.189	1.228	.660	.618	.543	.473	.408	.347	.292	.241	.195	.154	28
32	2.498	1.401	.752	.705	.619	.539	.465	.396	.333	.275	.223	.176	32
36	2.805	1.572	.844	.791	.696	.606	.522	.445	.373	.309	.250	.197	36
40	3.111	1.742	.934	.878	.772	.672	.579	.493	.414	.342	.277	.219	40
45	3.491	1.952	1.046	.983	.863	.752	.648	.552	.463	.383	.305	.245	45
50	3.867	2.159	1.156	1.087	.955	.831	.716	.610	.512	.423	.343	.271	50

TABLE IX.—DIFFERENCE IN ELEVATION OF RAILS ON CURVES

D	Velocity in Miles per Hour.											
	10	15	20	25	30	35	40	45	50	55	60	65
1°	.006	.013	.023	.036	.051	.070	.091	.116	.143	.173	.206	.241
2	.011	.026	.046	.071	.103	.140	.183	.231	.285	.345	.410	.481
3	.017	.039	.069	.107	.154	.210	.274	.346	.427	.516	.612	.717
4	.023	.051	.091	.143	.206	.280	.365	.461	.568	.685	.811	.947
5	.029	.064	.114	.179	.257	.349	.455	.574	.707	.851		
6	.034	.077	.137	.214	.308	.418	.545	.687	.844			
7	.040	.090	.160	.250	.359	.487	.634	.798	.979			
8	.046	.103	.183	.285	.410	.556	.723	.908				
9	.051	.116	.206	.320	.460	.624	.811					
10	.057	.129	.228	.356	.511	.692	.893					
11	.063	.142	.251	.391	.561	.760	.984					
12	.069	.154	.274	.427	.611	.826						
14	.080	.180	.319	.497	.711	.959						
16	.091	.206	.365	.567	.809							
18	.102	.231	.410	.637	.906							
20	.114	.256	.455	.707								
25	.141	.318	.563	.775								
30	.168	.380	.672	.844								
35	.195	.441	.778									
40	.222	.501	.881									
50	.276	.618										

TABLE VII.—COEFFICIENTS FOR VALVOID ARCS

I.—Ratio of $u = \frac{i}{\Delta}$.

L	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
300	.3518	.3516	.3514	.3510	.3506	.3500	.3493	.3485	.3476	.3466	.3455	.3444
400	.3437	.3436	.3433	.3430	.3426	.3421	.3415	.3408	.3399	.3390	.3380	.3368
500	.3400	.3398	.3396	.3393	.3389	.3383	.3379	.3372	.3364	.3356	.3345	3335
600	.3379	.3378	.3376	.3373	.3369	.3365	.3359	.3353	.3345	.3337	.3327	.3317
700	.3367	.3366	.3364	.3361	.3357	.3353	.3347	.3341	.3334	.3326	.3316	.3306
800	.3359	.3358	.3356	.3353	.3349	.3345	.3340	.3333	.3326	.3318	.3309	.3299
900	.3353	.3352	.3350	.3348	.3344	.3340	.3334	.3328	.3321	.3313	.3304	.3294
1000	.3350	.3348	.3346	.3344	.3340	.3336	.3331	.3324	.3317	.3310	.3301	.3291
1200	.3345	.3343	.3341	.3339	.3336	.3331	.3326	.3320	.3313	.3305	.3296	.3286
1500	.3340	.3339	.3337	.3335	.3331	.3327	.3322	.3316	.3309	.3301	.3202	.3283
2000	.3337	.3336	.2333	.3331	.3328	.3324	.3319	.3313	.3306	.3298	.3289	.3280

II.—Ratio of $v = \frac{r}{L}$.

L	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
300	.7706	.7683	.7643	.7588	.7518	.7432	.7332	.7218	.7090	.6949	.6795	6630
400	.7611	.7588	.7549	.7495	.7425	.7341	.7243	.7130	.7004	.6865	.6714	6551
500	.7568	.7545	.7506	.7452	.7384	.7300	.7202	.7091	.6966	.6828	.6678	6516
600	.7545	.7522	.7483	.7430	.7361	.7278	.7181	.7070	.6946	.6808	.6659	6498
700	.7531	.7508	.7469	.7416	.7348	.7265	.7168	.7057	.6933	.6797	.6648	6487
800	.7522	.7499	.7461	.7407	.7339	.7257	.7160	.7049	.6926	.6789	.6640	.6480
900	.7516	.7492	.7454	.7401	.7333	.7251	.7154	.7044	.6920	.6784	.6635	.6475
1000	.7512	.7489	.7450	.7397	.7329	.7247	.7150	.7040	.6917	.6780	.6632	.6472
1200	.7505	.7483	.7444	.7391	.7324	.7241	.7145	.7035	.6912	.6775	.6627	.6468
1500	.7501	.7478	.7440	.7387	.7319	.7237	.7141	.7031	.6908	.6772	.6624	.6464
2000	.7497	.7474	.7436	.7383	.7316	.7234	.7137	.7028	.6904	.6769	.6621	.6461

III.—Ratio of $l_{\prime} = \frac{l}{\Delta' - \Delta''}$ = Length of Valvoid Arc corresponding to a Change of One Degree in the Angle Δ.

L	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°
300	2.62	2.61	2.60	2.59	2.57	2.55	2.52	2.49	2.46	2.42	2.38	2.34
400	3.49	3.48	3.46	3.44	3.42	3.38	3.35	3.30	3.25	3.20	3.14	3.08
500	4.36	4.35	4.33	4.30	4.26	4.22	4.17	4.11	4.05	3.98	3.90	3.81
600	5.23	5.22	5.19	5.16	5.11	5.06	4.99	4.92	4.84	4.75	4.65	4.55
700	6.10	6.09	6.06	6.02	5.96	5.90	5.83	5.74	5.65	5.54	5.43	5.31
800	6.97	6.95	6.92	6.87	6.82	6.74	6.66	6.56	6.45	6.33	6.20	6.06
900	7.85	7.82	7.79	7.73	7.67	7.59	7.49	7.38	7.26	7.13	6.98	6.82
1000	8.72	8.69	8.65	8.59	8.52	8.43	8.32	8.20	8.07	7.92	7.75	7.58
1100	9.59	9.56	9.52	9.45	9.37	9.27	9.16	9.02	8.87	8.71	8.53	8.34
1200	10.46	10.43	10.38	10.31	10.22	10.11	9.99	9.84	9.68	9.50	9.31	9.09
1300	11.33	11.30	11.25	11.17	11.07	10.96	10.82	10.66	10.49	10.29	10.08	9.85
1400	12.21	12.17	12.11	12.03	11.93	11.80	11.65	11.48	11.29	11.08	10.86	10.61
1500	13.08	13.04	12.98	12.89	12.78	12.64	12.48	12.30	12.10	11.88	11.63	11.37
1600	13.95	13.91	13.84	13.75	13.63	13.49	13.32	13.12	12.91	12.67	12.41	12.13
1700	*14.82*	*14.78*	*14.71*	*14.61*	14.48	14.33	14.15	13.94	13.71	13.46	13.18	12.88
1800	*15.69*	*15.65*	*15.57*	*15.47*	15.33	15.17	14.98	14.76	14.52	14.25	13.96	13.64
1900	*16.57*	*16.52*	*16.44*	*16.33*	16.19	16.01	15.81	15.58	15.33	15.04	14.73	14.40
2000	*17.44*	*17.39*	*17.30*	17.19	17.04	16.86	16.65	16.40	16.13	15.83	15.51	15.16

TABLE VIII.—MIDDLE ORDINATES FOR RAILS

D	Length of Rail-Chord.												D
	60	45	33	32	30	28	26	24	22	20	18	16	
1°	.078	.043	.024	.022	.020	.017	.015	.013	.011	.009	.007	.006	1°
2	.157	.088	.047	.045	.039	.034	.030	.025	.021	.017	.014	.011	2
3	.235	.132	.070	.067	.059	.051	.044	.038	.032	.026	.021	.017	3
4	.314	.176	.094	.089	.079	.068	.059	.050	.042	.035	.028	.022	4
5	.391	.221	.118	.112	.098	.086	.074	.063	.053	.044	.035	.028	5
6	.471	.264	.143	.134	.118	.103	.088	.075	.063	.052	.042	.034	6
7	.550	.309	.166	.156	.137	.120	.103	.088	.074	.061	.049	.039	7
8	.628	.353	.190	.179	.157	.137	.118	.100	.084	.070	.057	.045	8
9	.706	.397	.214	.201	.177	.154	.133	.113	.095	.078	.064	.050	9
10	.785	.441	.237	.223	.196	.171	.147	.126	.105	.087	.071	.056	10
11	.863	.485	.261	.245	.216	.188	.162	.138	.116	.096	.078	.061	11
12	.942	.529	.285	.268	.235	.205	.177	.151	.127	.105	.085	.067	12
14	1.098	.617	.332	.312	.274	.238	.206	.175	.147	.122	.099	.078	14
16	1.255	.705	.379	.356	.313	.273	.235	.200	.168	.139	.113	.089	16
18	1.411	.793	.426	.400	.352	.307	.264	.225	.189	.156	.127	.100	18
20	1.567	.880	.473	.445	.391	.340	.293	.250	.210	.174	.141	.111	20
24	1.878	1.055	.567	.531	.467	.407	.351	.299	.251	.207	.168	.133	24
28	2.189	1.228	.660	.618	.543	.473	.408	.347	.292	.241	.195	.154	28
32	2.498	1.401	.752	.705	.619	.539	.465	.396	.333	.275	.223	.176	32
36	2.805	1.572	.844	.791	.696	.606	.522	.445	.373	.309	.250	.197	36
40	3.111	1.742	.934	.878	.772	.672	.579	.493	.414	.342	.277	.219	40
45	3.491	1.952	1.046	.983	.863	.752	.648	.552	.463	.383	.305	.245	45
50	3.867	2.159	1.156	1.087	.955	.831	.716	.610	.512	.423	.343	.271	50

TABLE IX.—DIFFERENCE IN ELEVATION OF RAILS ON CURVES

D	Velocity in Miles per Hour.											
	10	15	20	25	30	35	40	45	50	55	60	65
1°	.006	.013	.023	.036	.051	.070	.091	.116	.143	.173	.206	.241
2	.011	.026	.046	.071	.103	.140	.183	.231	.285	.345	410	.481
3	.017	.039	.069	.107	.154	.210	.274	.346	.427	.516	.612	.717
4	.023	.051	.091	.143	.206	.280	.365	.461	.568	.685	.811	.947
5	.029	.064	.114	.179	.257	.349	.455	.574	.707	.851		
6	.034	.077	.137	.214	.308	.418	.545	.687	.844			
7	.040	.090	.160	.250	.359	.487	.634	.798	.979			
8	.046	.103	.183	.285	.410	.556	.723	.908				
9	.051	.116	.206	.320	.460	.624	.811					
10	.057	.129	.228	.356	.511	.692	.898					
11	.063	.142	.251	.391	.561	.760	.984					
12	.069	.154	.274	.427	.611	.826						
14	.080	.180	.319	.497	.711	.959						
16	.091	.206	.365	.567	.809							
18	.102	.231	.410	.637	.906							
20	.114	.256	.455	.707								
25	.141	.318	.563	.775								
30	.168	.380	.672	.844								
35	.195	.441	.778									
40	.222	.501	.881									
50	.276	.618										

TABLE X.—INCHES IN DECIMALS OF A FOOT

In.	0	1	2	3	4	5	6	7	8	9	10	11	In.
0	Foot	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167	0
1-32	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193	1-32
1-16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219	1-16
3-32	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245	3-32
1-8	.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	.9271	1-8
5-32	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297	5-32
3-16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323	3-16
7-32	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349	7-32
1-4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375	1-4
9-32	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401	9-32
5-16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427	5-16
11-32	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453	11-32
3-8	.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	.9479	3-8
13-32	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	.9505	13-32
7-16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531	7-16
15-32	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557	15-32
1-2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583	1-2
17-32	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609	17-32
9-16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635	9-16
19-32	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661	19-32
5-8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688	5-8
21-32	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714	21-32
11-16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740	11-16
23-32	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766	23-32
3-4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792	3-4
25-32	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818	25-32
13-16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844	13-16
27-32	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870	27-32
7-8	.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	.9896	7-8
29-32	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922	29-32
15-16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948	15-16
31-32	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974	31-32
	0	1	2	3	4	5	6	7	8	9	10	11	

Defl. Angle 20 m. Chord.	Radius in Meters.	Log. of Radius.	Mid. Ord.	Tang. Off.	Degree of Equiv. U. S. Curve.	Defl. Angle 20 m. Chord.
0° 10′	3437.75	3.536274	.015	.058	0° 30′	0° 10′
20	1718.89	3.235246	.029	.116	1 01	20
30	1145.93	3.059158	.044	.175	1 31	30
40	859.46	2.934224	.058	.233	2 02	40
50	687.57	2.837319	.073	.291	2 32	50
1 00	572.99	2.758145	.087	.349	3 03	1 00
10	491.14	2.691206	.102	.407	3 33	10
20	429.76	2.633223	.116	.465	4 04	20
30	382.02	2.582081	.131	.524	4 34	30
40	343.82	2.536335	.145	.582	5 05	40
50	312.58	2.494955	.160	.640	5 35	50
2 00	286.54	2.457181	.175	.698	6 06	2 00
10	264.51	2.422434	.189	.756	6 36	10
20	245.62	2.390266	.204	.814	7 07	20
30	229.26	2.360320	.218	.872	7 37	30
40	214.94	2.332311	.233	.931	8 08	40
50	202.30	2.306002	.247	.989	8 38	50
3 00	191.07	2.281200	.262	1.047	9 09	3 00
10	181.03	2.257741	.276	1.105	9 40	10
20	171.98	2.235489	.291	1.163	10 10	20
30	163.80	2.214325	.306	1.221	10 41	30
40	156.37	2.194148	.320	1.279	11 11	40
50	149.58	2.174870	.335	1.337	11 42	50
4 00	143.36	2.156416	.349	1.395	12 12	4 00
10	137.63	2.138717	.364	1.453	12 43	10
20	132.35	2.121715	.378	1.511	13 13	20
30	127.45	2.105357	.393	1.569	13 44	30
40	122.91	2.089596	.407	1.627	14 15	40
50	118.68	2.074391	.422	1.685	14 45	50
5 00	114.737	2.059704	.437	1.743	15 16	5 00
10	111.045	2.045501	.451	1.801	15 47	10
20	107.585	2.031751	.466	1.859	16 17	20
30	104.334	2.018427	.480	1.917	16 48	30
40	101.275	2.005503	.495	1.975	17 19	40
50	98.391	1.992956	.509	2.033	17 49	50
6 00	95.668	1.980765	.524	2.091	18 20	6 00
10	93.092	1.968911	.539	2.148	18 51	10
20	90.652	1.957375	.553	2.206	19 21	20
30	88.337	1.946141	.568	2.264	19 52	30
40	86.138	1.935194	.582	2.322	20 23	40
50	84.047	1.924520	.597	2.380	20 54	50
7 00	82.055	1.914105	.612	2.437	21 24	7 00
10	80.156	1.903938	.626	2.495	21 55	10
20	78.344	1.894008	.641	2.553	22 26	20
30	76.613	1.884302	.655	2.611	22 57	30
40	74.957	1.874813	.670	2.668	23 28	40
50	73.372	1.865530	.685	2.726	23 59	50
8 00	71.853	1.856445	.699	2.783	24 29	8 00
10	70.396	1.847549	.714	2.841	25 00	10
20	68.998	1.838836	.729	2.899	25 31	20
30	67.655	1.830298	.743	2.956	26 02	30
40	66.363	1.821928	.758	3.014	26 33	40
50	65.121	1.813720	.772	3.071	27 04	50
9 00	63.925	1.805668	.787	3.129	27 35	9 00
10	62.772	1.797766	.802	3.186	28 06	10
20	61.661	1.790008	.816	3.244	28 37	20
30	60.589	1.782891	.831	3.301	29 08	30
40	59.554	1.774908	.846	3.358	29 39	40
50	58.554	1.767556	.860	3.416	30 10	50
10° 00′	57.588	1.760330	.875	3.473	30 41	10° 00′

TABLE XII.—ACRES FOR RIGHT OF WAY 100 FT. WIDE

Sta. of 100′	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Sta. of 100′
0	0.000	0.023	0.046	0.069	0.092	0.115	0.138	0.161	0.184	0.207	0
1	0.230	0.252	0.275	0.298	0.321	0.344	0.367	0.390	0.413	0.436	1
2	0.459	0.482	0.505	0.528	0.551	0.574	0.597	0.620	0.643	0.666	2
3	0.689	0.712	0.735	0.757	0.780	0.803	0.826	0.849	0.872	0.895	3
4	0.918	0.941	0.964	0.987	1.010	1.033	1.056	1.079	1.102	1.125	4
5	1.148	1.171	1.194	1.217	1.240	1.263	1.286	1.309	1.331	1.354	5
6	1.377	1.400	1.423	1.446	1.469	1.492	1.515	1.538	1.561	1.584	6
7	1.608	1.631	1.654	1.677	1.700	1.723	1.746	1.769	1.792	1.814	7
8	1.837	1.860	1.882	1.905	1.928	1.951	1.974	1.997	2.020	2.043	8
9	2.066	2.089	2.112	2.135	2.158	2.181	2.204	2.227	2.250	2.273	9
10	2.296	2.319	2.342	2.365	2.388	2.410	2.433	2.456	2.479	2.502	10
11	2.525	2.548	2.571	2.594	2.617	2.640	2.663	2.686	2.709	2.732	11
12	2.755	2.778	2.801	2.824	2.847	2.870	2.893	2.916	2.938	2.961	12
13	2.984	3.007	3.030	3.053	3.076	3.099	3.122	3.145	3.168	3.191	13
14	3.214	3.237	3.260	3.283	3.306	3.329	3.352	3.375	3.398	3.421	14
15	3.444	3.466	3.489	3.512	3.535	3.558	3.581	3.604	3.627	3.650	15
16	3.673	3.696	3.719	3.742	3.765	3.788	3.811	3.834	3.857	3.880	16
17	3.903	3.926	3.949	3.972	3.994	4.017	4.040	4.063	4.086	4.109	17
18	4.132	4.155	4.178	4.201	4.224	4.247	4.270	4.293	4.316	4.339	18
19	4.362	4.385	4.408	4.431	4.454	4.477	4.500	4.522	4.545	4.568	19
20	4.591	4.614	4.637	4.660	4.683	4.706	4.729	4.752	4.775	4.798	20
21	4.821	4.844	4.867	4.890	4.913	4.936	4.959	4.982	5.005	5.028	21
22	5.051	5.073	5.096	5.119	5.142	5.165	5.188	5.211	5.234	5.257	22
23	5.280	5.303	5.326	5.349	5.372	5.395	5.418	5.441	5.464	5.487	23
24	5.510	5.533	5.556	5.579	5.601	5.624	5.647	5.670	5.693	5.716	24
25	5.739	5.762	5.785	5.808	5.831	5.854	5.877	5.900	5.923	5.946	25
26	5.969	5.992	6.015	6.038	6.061	6.084	6.107	6.129	6.152	6.175	26
27	6.198	6.221	6.244	6.267	6.290	6.313	6.336	6.359	6.382	6.405	27
28	6.428	6.451	6.474	6.497	6.520	6.543	6.566	6.589	6.612	6.635	28
29	6.657	6.680	6.703	6.726	6.749	6.772	6.795	6.818	6.841	6.864	29
30	6.887	6.910	6.933	6.956	6.979	7.002	7.025	7.048	7.071	7.094	30
31	7.117	7.140	7.163	7.185	7.208	7.231	7.254	7.277	7.300	7.323	31
32	7.346	7.369	7.392	7.415	7.438	7.461	7.484	7.507	7.530	7.553	32
33	7.576	7.599	7.622	7.645	7.668	7.691	7.714	7.736	7.759	7.782	33
34	7.805	7.828	7.851	7.874	7.897	7.920	7.943	7.966	7.989	8.012	34
35	8.035	8.058	8.081	8.104	8.127	8.150	8.173	8.196	8.219	8.242	35
36	8.264	8.287	8.310	8.333	8.356	8.379	8.402	8.425	8.448	8.471	36
37	8.494	8.517	8.540	8.563	8.586	8.609	8.632	8.655	8.678	8.701	37
38	8.724	8.747	8.770	8.792	8.815	8.838	8.861	8.884	8.907	8.930	38
39	8.953	8.976	8.999	9.022	9.045	9.068	9.091	9.114	9.137	9.160	39
40	9.183	9.206	9.229	9.252	9.275	9.298	9.320	9.343	9.366	9.389	40
41	9.412	9.435	9.458	9.481	9.504	9.527	9.550	9.573	9.596	9.619	41
42	9.642	9.665	9.688	9.711	9.734	9.757	9.780	9.803	9.826	9.848	42
43	9.871	9.894	9.917	9.940	9.963	9.986	10.009	10.032	10.055	10.078	43
44	10.101	10.124	10.147	10.170	10.193	10.216	10.239	10.262	10.285	10.308	44
45	10.331	10.354	10.377	10.399	10.422	10.445	10.468	10.491	10.514	10.537	45
46	10.560	10.583	10.606	10.629	10.652	10.675	10.698	10.721	10.744	10.767	46
47	10.790	10.813	10.836	10.859	10.882	10.905	10.927	10.950	10.973	10.996	47
48	11.019	11.042	11.065	11.088	11.111	11.134	11.157	11.180	11.203	11.226	48
49	11.249	11.272	11.295	11.318	11.341	11.364	11.387	11.410	11.433	11.455	49
50	11.478	11.501	11.524	11.547	11.570	11.593	11.616	11.639	11.662	11.685	50
51	11.708	11.731	11.754	11.777	11.800	11.823	11.846	11.869	11.892	11.915	51
52	11.938	11.961	11.983	12.006	12.029	12.052	12.075	12.098	12.121	12.144	52

Speed in Miles per Hour.	Velocity Heads in Feet.									
	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03
1	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.13
2	0.14	0.16	0.17	0.19	0.20	0.22	0.24	0.26	0.28	0.30
3	0.32	0.34	0.36	0.39	0.41	0.43	0.46	0.49	0.51	0.54
4	0.57	0.60	0.63	0.66	0.69	0.72	0.75	0.78	0.82	0.85
5	0.89	0.92	0.96	1.00	1.04	1.07	1.11	1.15	1.19	1.24
6	1.28	1.32	1.36	1.41	1.45	1.50	1.55	1.59	1.64	1.69
7	1.74	1.79	1.84	1.89	1.94	2.00	2.05	2.10	2.16	2.22
8	2.27	2.33	2.39	2.45	2.50	2.56	2.63	2.69	2.75	2.81
9	2.88	2.94	3.00	3.07	3.14	3.20	3.27	3.34	3.41	3.48
10	3.55	3.62	3.69	3.77	3.84	3.91	3.99	4.06	4.14	4.22
11	4.30	4.37	4.45	4.53	4.61	4.69	4.78	4.86	4.94	5.03
12	5.11	5.20	5.28	5.37	5.46	5.55	5.64	5.73	5.82	5.91
13	6.00	6.09	6.19	6.28	6.37	6.47	6.57	6.66	6.76	6.86
14	6.96	7.06	7.16	7.26	7.36	7.46	7.57	7.67	7.78	7.88
15	7.99	8.09	8.20	8.31	8.42	8.53	8.64	8.75	8.86	8.97
16	9.09	9.20	9.32	9.43	9.55	9.66	9.78	9.89	10.02	10.14
17	10.26	10.38	10.50	10.62	10.75	10.87	11.00	11.12	11.25	11.37
18	11.50	11.63	11.76	11.89	12.02	12.15	12.28	12.41	12.55	12.68
19	12.82	12.95	13.09	13.22	13.36	13.50	13.64	13.78	13.92	14.06
20	14.20	14.34	14.49	14.63	14.77	14.92	15.06	15.21	15.36	15.51
21	15.66	15.80	15.96	16.11	16.26	16.41	16.56	16.72	16.87	17.03
22	17.18	17.34	17.50	17.65	17.81	17.97	18.13	18.29	18.45	18.62
23	18.78	18.94	19.11	19.27	19.44	19.60	19.77	19.94	20.11	20.28
24	20.45	20.62	20.79	20.96	21.14	21.31	21.48	21.66	21.83	22.01
25	22.19	22.37	22.54	22.72	22.90	23.08	23.27	23.45	23.63	23.81
26	24.00	24.18	24.37	24.55	24.74	24.93	25.12	25.31	25.50	25.69
27	25.88	26.07	26.26	26.46	26.65	26.85	27.04	27.24	27.44	27.63
28	27.83	28.03	28.23	28.43	28.63	28.83	29.04	29.24	29.45	29.65
29	29.86	30.06	30.27	30.48	30.68	30.89	31.10	31.31	31.53	31.74
30	31.95	32.16	32.38	32.59	32.81	33.02	33.24	33.46	33.68	33.90
31	34.12	34.34	34.56	34.78	35.00	35.22	35.45	35.67	35.90	36.13
32	36.35	36.58	36.81	37.04	37.27	37.50	37.73	37.96	38.19	38.43
33	38.66	38.89	39.13	39.37	39.60	39.84	40.08	40.32	40.56	40.80
34	41.04	41.28	41.52	41.77	42.01	42.25	42.50	42.75	42.99	43.24
35	43.49	43.74	43.99	44.24	44.49	44.74	44.99	45.24	45.50	45.75
36	46.01	46.26	46.52	46.78	47.04	47.29	47.55	47.81	48.08	48.34
37	48.60	48.86	49.13	49.39	49.66	49.92	50.19	50.46	50.72	50.99
38	51.26	51.53	51.80	52.07	52.35	52.62	52.89	53.17	53.44	53.72
39	54.00	54.27	54.55	54.83	55.11	55.39	55.67	55.95	56.23	56.52
40	56.80	57.08	57.37	57.66	57.94	58.23	58.52	58.81	59.09	59.38
41	59.68	59.97	60.26	60.55	60.85	61.14	61.43	61.73	62.03	62.32
42	62.62	62.92	63.22	63.52	63.82	64.12	64.42	64.73	65.03	65.33
43	65.64	65.95	66.25	66.56	66.87	67.17	67.48	67.79	68.10	68.42
44	68.73	69.04	69.35	69.67	69.98	70.30	70.62	70.93	71.25	71.57
45	71.89	72.21	72.53	72.85	73.17	73.49	73.82	74.14	74.47	74.79
46	75.12	75.44	75.77	76.10	76.43	76.76	77.09	77.42	77.75	78.09
47	78.42	78.75	79.09	79.42	79.76	80.10	80.43	80.77	81.11	81.45
48	81.79	82.13	82.48	82.82	83.16	83.50	83.85	84.19	84.54	84.89
49	85.24	85.58	85.93	86.28	86.63	86.98	87.34	87.69	88.04	88.40

	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
50	88.75	92.34	95.99	99.72	103.52	107.39	111.33	115.31	119.42	123.58
60	127.80	132.10	136.46	140.90	145.41	145.99	154.64	159.36	164.15	169.02
70	173.95	178.96	184.03	189.18	194.40	199.69	205.05	210.48	215.98	221.58
80	227.20	232.92	238.70	244.56	250.49	256.49	262.56	268.70	274.91	281.20
90	287.55	293.98	300.47	307.04	313.68	320.39	327.17	334.02	340.94	347.9

Feet per Station.	Feet per Mile.	Inclination.	Feet per Station.	Feet per Mile.	Inclination.	Feet per Station.	Feet per Mile.	Inclination.
		° ′ ″			° ′ ″			° ′ ″
.01	.528	21	.51	26.928	17 32	1.01	53.328	34 43
.02	1.056	41	.52	27.456	17 53	1.02	53.856	35 04
.03	1.584	1 02	.53	27.984	18 13	1.03	54.384	35 24
.04	2.112	1 23	.54	28.512	18 34	1.04	54.912	35 45
.05	2.640	1 43	.55	29.040	18 54	1.05	55.440	36 05
.06	3.168	2 04	.56	29.568	19 15	1.06	55.968	36 26
.07	3.696	2 24	.57	30.096	19 36	1.07	56.496	36 47
.08	4.224	2 45	.58	30.624	19 56	1.08	57.024	37 08
.09	4.752	3 06	.59	31.152	20 17	1.09	57.552	37 28
.10	5.280	3 26	.60	31.680	20 38	1.10	58.080	37 49
.11	5.808	3 47	.61	32.208	20 58	1.11	58.608	38 09
.12	6.336	4 08	.62	32.736	21 19	1.12	59.136	38 30
.13	6.864	4 28	.63	33.264	21 39	1.13	59.664	38 51
.14	7.392	4 49	.64	33.792	22 00	1.14	60.192	39 11
.15	7.920	5 09	.65	34.320	22 21	1.15	60.720	39 32
.16	8.448	5 30	.66	34.848	22 41	1.16	61.248	39 53
.17	8.976	5 51	.67	35.376	23 02	1.17	61.776	40 13
.18	9.504	6 11	.68	35.904	23 23	1.18	62.304	40 34
.19	10.032	6 32	.69	36.432	23 43	1.19	62.832	40 54
.20	10.560	6 53	.70	36.960	24 04	1.20	63.360	41 15
.21	11.088	7 13	.71	37.488	24 24	1.21	63.888	41 35
.22	11.616	7 34	.72	38.016	24 45	1.22	64.416	41 56
.23	12.144	7 54	.73	38.544	25 06	1.23	64.944	42 17
.24	12.672	8 15	.74	39.072	25 26	1.24	65.472	42 38
.25	13.200	8 36	.75	39.600	25 47	1.25	66.000	42 58
.26	13.728	8 56	.76	40.128	26 08	1.26	66.528	43 19
.27	14.256	9 17	.77	40.656	26 28	1.27	67.056	43 39
.28	14.784	9 38	.78	41.184	26 49	1.28	67.584	44 00
.29	15.312	9 58	.79	41.712	27 09	1.29	68.112	44 21
.30	15.840	10 19	.80	42.240	27 30	1.30	68.640	44 41
.31	16.368	10 39	.81	42.768	27 51	1.31	69.168	45 02
.32	16.896	11 00	.82	43.296	28 11	1.32	69.696	45 23
.33	17.424	11 21	.83	43.824	28 32	1.33	70.224	45 43
.34	17.952	11 41	.84	44.352	28 53	1.34	70.752	46 04
.35	18.480	12 02	.85	44.880	29 13	1.35	71.280	46 24
.36	19.008	12 23	.86	45.408	29 34	1.36	71.808	46 45
.37	19.536	12 43	.87	45.936	29 54	1.37	72.336	47 06
.38	20.064	13 04	.88	46.464	30 15	1.38	72.864	47 26
.39	20.592	13 24	.89	46.992	30 36	1.39	73.392	47 47
.40	21.120	13 45	.90	47.520	30 57	1.40	73.920	48 08
.41	21.648	14 06	.91	48.048	31 17	1.41	74.448	48 28
.42	22.176	14 26	.92	48.576	31 38	1.42	74.976	48 49
.43	22.704	14 47	.93	49.104	31 58	1.43	75.504	49 09
.44	23.232	15 08	.94	49.632	32 19	1.44	76.032	49 30
.45	23.760	15 28	.95	50.160	32 39	1.45	76.560	49 51
.46	24.288	15 49	.96	50.688	33 00	1.46	77.088	50 11
.47	24.816	16 09	.97	51.216	33 21	1.47	77.616	50 32
.48	25.344	16 30	.98	51.744	33 41	1.48	78.144	50 52
.49	25.872	16 51	.99	52.272	34 02	1.49	78.672	51 13
.50	26.400	17 11	1.00	52.800	34 23	1.50	79.200	51 34

Feet per Station.	Feet per Mile.	Inclination.	Feet per Station.	Feet per Mile.	Inclination.	Feet per Station.	Feet per Mile.	Inclination.
		° ′ ″			° ′ ″			° ′ ″
1.51	79.728	51 54	2.05	108.240	1 10 28	5.10	269.280	2 55 10
1.52	80.256	52 15	2.10	110.880	1 12 11	5.20	274.560	2 58 36
1.53	80.784	52 36	2.15	113.520	1 13 54	5.30	279.840	3 02 01
1.54	81.312	52 56	2.20	116.160	1 15 37	5.40	285.120	3 05 27
1.55	81.840	53 17	2.25	118.800	1 17 20	5.50	290.400	3 08 53
1.56	82.368	53 37	2.30	121.440	1 19 03	5.60	295.680	3 12 19
1.57	82.896	53 58	2.35	124.080	1 20 46	5.70	300.960	3 15 44
1.58	83.424	54 19	2.40	126.720	1 22 29	5.80	306.240	3 19 10
1.59	83.952	54.39	2.45	129.360	1 24 12	5.90	311.520	3 22 36
1.60	84.480	55 00	2.50	132.000	1 25 56	6.00	316.800	3 26 01
1.61	85.008	55 21	2.55	134.640	1 27 39	6.10	322.080	3 29 27
1.62	85.536	55 41	2.60	137.280	1 29 22	6.20	327.360	3 32 52
1.63	86.064	56 02	2.65	139.920	1 31 05	6.30	332.640	3 36 18
1.64	86.592	56 22	2.70	142.560	1 32 48	6.40	337.920	3 39 43
1.65	87.120	56 43	2.75	145.200	1 34 31	6.50	343.200	3 43 08
1.66	87.648	57 04	2.80	147.840	1 36 14	6.60	348.480	3 46 34
1.67	88.176	57 24	2.85	150.480	1 37 57	6.70	353.760	3 49 59
1.68	88.704	57 45	2.90	153.120	1 39 40	6.80	359.040	3 53 24
1.69	89.232	58 06	2.95	155.760	1 41 23	6.90	364.320	3 56 50
1.70	89.760	58 26	3.00	158.400	1 43 06	7.00	369.600	4 00 15
1.71	90.288	58 47	3.05	161.040	1 44 49	7.10	374.880	4 03 40
1.72	90.816	59 07	3.10	163.680	1 46 32	7.20	380.160	4 07 06
1.73	91.344	59 28	3.15	166.320	1 48 15	7.30	385.440	4 10 31
1.74	91.872	59 49	3.20	168.960	1 49 58	7.40	390.720	4 13 56
1.75	92.400	1 00 09	3.25	171.600	1 51 41	7.50	396.000	4 17 21
1.76	92.928	1 00 30	3.30	174.240	1 53 24	7.60	401.280	4 20 46
1.77	93.456	1 00 51	3.35	176.880	1 55 07	7.70	406.560	4 24 11
1.78	93.984	1 01 11	3.40	179.520	1 56 50	7.80	411.840	4 27 36
1.79	94.512	1 01 32	3.45	182.160	1 58 33	7.90	417.120	4 31 01
1.80	95.040	1 01 52	3.50	184.800	2 00 16	8.00	422.400	4 34 26
1.81	95.568	1 02 13	3.55	187.440	2 01 59	8.10	427.680	4 37 51
1.82	96.096	1 02 34	3.60	190.080	2 03 42	8.20	432.960	4 41 16
1.83	96.624	1 02 54	3.65	192.720	2 05 25	8.30	438.240	4 44 41
1.84	97.152	1 03 15	3.70	195.360	2 07 08	8.40	443.520	4 48 06
1.85	97.680	1 03 35	3.75	198.000	2 08 51	8.50	448.800	4 51 30
1.86	98.208	1 03 56	3.80	200.640	2 10 34	8.60	454.080	4 54 55
1.87	98.736	1 04 17	3.85	203.280	2 12 17	8.70	459.360	4 58 20
1.88	99.264	1 04 37	3.90	205.920	2 14 00	8.80	464.640	5 01 44
1.89	99 792	1 04 58	3.95	208.560	2 15 43	8.90	469.920	5 05 10
1.90	100.320	1 05 19	4.00	211.200	2 17 26	9.00	475.200	5 08 34
1.91	100.848	1 05 39	4.10	216.480	2 20 52	9.10	480.480	5 11 59
1.92	101.376	1 06 00	4.20	221.760	2 24 18	9.20	485.760	5 15 23
1.93	101.904	1 06 20	4.30	227.040	2 27 44	9.30	491.040	5 18 48
1.94	102.432	1 06 41	4.40	232.320	2 31 10	9.40	496.320	5 22 12
1.95	102.960	1 07 02	4.50	237.600	2 34 36	9.50	501.600	5 25 37
1.96	103.488	1 07 22	4.60	242.880	2 38 01	9.60	506.880	5 29 01
1.97	104.016	1 07 43	4.70	248.160	2 41 27	9.70	512.160	5 32 25
1.98	104.544	1 08 04	4.80	253.440	2 44 53	9.80	517.440	5 35 50
1.99	105.072	1 08 24	4.90	258.720	2 48 19	9.90	522.720	5 39 14
2.00	105.600	1 08 45	5.00	264.000	2 51 45	10.00	528.000	5 42 38

Barometer. Inches = *h*.	0.00	0.02	0.04	0.06	0.08	Diff. per .002 in.
19 .0	16832	16860	16888	16915	16943	2.8
.1	16970	16997	17025	17052	17080	2.8
.2	17107	17134	17162	17189	17216	2.7
.3	17243	17270	17298	17325	17352	2.7
.4	17379	17406	17433	17460	17487	2.7
.5	17514	17540	17567	17594	17621	2.7
.6	17648	17674	17701	17728	17755	2.7
.7	17781	17808	17834	17861	17887	2.7
.8	17914	17940	17967	17993	18020	2.7
.9	18046	18072	18099	18125	18151	2.6
20 .0	18178	18204	18230	18256	18282	2.6
.1	18308	18334	18360	18386	18412	2.6
.2	18438	18464	18490	18516	18542	2.6
.3	18568	18594	18620	18645	18671	2.6
.4	18697	18723	18748	18774	18799	2.6
.5	18825	18851	18876	18902	18927	2.6
.6	18953	18978	19004	19029	19054	2.5
.7	19080	19105	19130	19156	19181	2.5
.8	19206	19231	19256	19282	19307	2.5
.9	19332	19357	19382	19407	19432	2.5
21 .0	19457	19482	19507	19532	19557	2.5
.1	19582	19606	19631	19656	19681	2.5
.2	19706	19730	19755	19780	19804	2.5
.3	19829	19854	19878	19903	19927	2.5
.4	19952	19976	20001	20025	20050	2.5
.5	20074	20098	20123	20147	20172	2.5
.6	20196	20220	20244	20269	20293	2.4
.7	20317	20341	20365	20389	20413	2.4
.8	20438	20462	20486	20510	20534	2.4
.9	20558	20581	20605	20629	20653	2.4
22 .0	20677	20701	20725	20748	20772	2.4
.1	20796	20820	20843	20867	20891	2.4
.2	20914	20938	20962	20985	21009	2.4
.3	21032	21056	21079	21103	21126	2.4
.4	21150	21173	21196	21220	21243	2.3
.5	21266	21290	21313	21336	21359	2.3
.6	21383	21406	21429	21452	21475	2.3
.7	21498	21522	21545	21568	21591	2.3
.8	21614	21637	21660	21683	21706	2.3
.9	21728	21751	21774	21797	21820	2.3
23 .0	21843	21866	21888	21911	21934	2.3
.1	21957	21979	22002	22025	22047	2.3
.2	22070	22092	22115	22138	22160	2.3
.3	22183	22205	22228	22250	22272	2.2
.4	22295	22317	22340	22362	22384	2.2
.5	22407	22429	22451	22474	22496	2.2
.6	22518	22540	22562	22585	22607	2.2
.7	22629	22651	22673	22695	22717	2.2
.8	22739	22761	22783	22805	22827	2.2
.9	22849	22871	22893	22915	22937	2.2
24 .0	22959	22981	23003	23024	23046	2.2
.1	23068	23090	23111	23133	23155	2.2
.2	23176	23198	23220	23241	23263	2.2
.3	23285	23306	23328	23349	23371	2.2
.4	23392	23414	23435	23457	23478	2.2
.5	23500	23521	23542	23564	23585	2.1
.6	23606	23628	23649	23670	23692	2.1
.7	23713	23734	23755	23776	23798	2.1
.8	23819	23840	23861	23882	23903	2.1
	23924	23945	23966	23987	24008	2.1

Barometer. Inches $=h$.	0.00	0.02	0.04	0.06	0.08	Diff. per .02 in.
25 .0	24029	24050	24071	24092	24113	2.1
.1	24134	24155	24176	24197	24217	2.1
.2	24238	24259	24280	24301	24321	2.1
.3	24342	24363	24384	24404	24425	2.1
.4	24446	24466	24487	24508	24528	2.1
.5	24549	24569	24590	24610	24631	2.1
.6	24651	24672	24693	24713	24733	2.0
.7	24754	24774	24794	24815	24835	2.0
.8	24855	24876	24896	24916	24937	2.0
.9	24957	24977	24997	25018	25038	2.0
26 .0	25058	25078	25098	25118	25138	2.0
.1	25159	25179	25199	25219	25239	2.0
.2	25259	25279	25299	25319	25339	2.0
.3	25359	25379	25399	25419	25438	2.0
.4	25458	25478	25498	25518	25538	2.0
.5	25557	25577	25597	25617	25637	2.0
.6	25656	25676	25696	25715	25735	2.0
.7	25755	25774	25794	25813	25833	2.0
.8	25853	25872	25892	25911	25931	2.0
.9	25950	25970	25989	26009	26028	2.0
27 .0	26048	26067	26086	26106	26125	1.9
.1	26145	26164	26183	26203	26222	1.9
.2	26241	26260	26280	26299	26318	1.9
.3	26337	26357	26376	26395	26414	1.9
.4	26433	26452	26472	26491	26510	1.9
.5	26529	26548	26567	26586	26605	1.9
.6	26624	26643	26662	26681	26700	1.9
.7	26719	26738	26757	26776	26795	1.9
.8	26813	26832	26851	26870	26889	1.9
.9	26908	26926	26945	26964	26983	1.9
28 .0	27001	27020	27039	27058	27076	1.9
.1	27095	27114	27132	27151	27169	1.9
.2	27188	27207	27225	27244	27262	1.9
.3	27281	27299	27318	27336	27355	1.8
.4	27373	27392	27410	27429	27447	1.8
.5	27466	27484	27503	27521	27539	1.8
.6	27557	27576	27594	27612	27631	1.8
.7	27649	27667	27685	27704	27722	1.8
.8	27740	27758	27777	27795	27813	1.8
.9	27831	27849	27867	27885	27904	1.8
29 .0	27922	27940	27958	27976	27994	1.8
.1	28012	28030	28048	28066	28084	1.8
.2	28102	28120	28138	28156	28174	1.8
.3	28192	28209	28227	28245	28263	1.8
.4	28281	28299	28317	28334	28352	1.8
.5	28370	28388	28405	28423	28441	1.8
.6	28459	28476	28494	28512	28529	1.8
.7	28547	28565	28582	28600	28618	1.8
.8	28635	28653	28670	28688	28706	1.8
.9	28723	28741	28758	28776	28793	1.8
30 .0	28811	28828	28846	28863	28881	1.8
.1	28898	28915	28933	28950	28968	1.8
.2	28985	29002	29020	29037	29054	1.7
.3	29072	29089	29106	29124	29141	1.7
.4	29158	29175	29192	29210	29227	1.7
.5	29244	29261	29278	29296	29313	1.7
.6	29330	29347	29364	29381	29398	1.7
.7	29416	29433	29450	29467	29484	1.7
.8	29501	29518	29535	29552	29569	1.7
.9	29586	29603	29620	29637	29654	1.7

TABLE XVI.—COEFFICIENT OF CORRECTION FOR TEMPERATURE

$t+t'$	$\frac{t+t'-64°}{900}$	$t+t'$	$\frac{t+t'-64°}{900}$	$t+t'$	$\frac{t+t'-64°}{900}$	$t+t'$	$\frac{t+t'-64°}{900}$
20°	.0489	65°	+ .0011	110°	+ .0511	155°	.1011
21	− .0478	66	.0022	111	.0522	156	.1022
22	.0467	67	.0033	112	.0533	157	.1033
23	.0456	68	.0044	113	.0544	158	.1044
24	.0444	69	.0056	114	.0556	159	.1056
25	.0433	70	.0067	115	.0567	160	.1067
26	.0422	71	.0078	116	.0578	161	.1078
27	.0411	72	.0089	117	.0589	162	.1089
28	.0400	73	.0100	118	.0600	163	.1100
29	.0389	74	.0111	119	.0611	164	.1111
30	.0378	75	.0122	120	+ .0622	165	.1122
31	− .0367	76	+ .0133	121	.0633	166	+ .1133
32	.0356	77	.0144	122	.0644	167	.1144
33	.0344	78	.0156	123	.0656	168	.1156
34	.0333	79	.0167	124	.0667	169	.1167
35	.0322	80	.0178	125	.0678	170	.1178
36	.0311	81	.0189	126	.0689	171	.1189
37	.0300	82	.0200	127	.0700	172	.1200
38	.0289	83	.0211	128	.0711	173	.1211
39	.0278	84	.0222	129	.0722	174	.1222
40	.0267	85	.0233	130	+ .0733	175	.1233
41	− .0256	86	+ .0244	131	.0744	176	+ .1244
42	.0244	87	.0256	132	.0756	177	.1256
43	.0233	88	.0267	133	.0767	178	.1267
44	.0222	89	.0278	134	.0778	179	.1278
45	.0211	90	.0289	135	.0789	180	.1289
46	.0200	91	.0300	136	.0800	181	.1300
47	.0189	92	.0311	137	.0811	182	.1311
48	.0178	93	.0322	138	.0822	183	.1322
49	.0167	94	.0333	139	.0833	184	.1333
50	− .0156	95	.0344	140	+ .0844	185	.1344
51	.0144	96	+ .0356	141	.0856	186	+ .1356
52	.0133	97	.0367	142	.0867	187	.1367
53	.0122	98	.0378	143	.0878	188	.1378
54	.0111	99	.0389	144	.0889	189	.1389
55	.0100	100	.0400	145	.0900	190	.1400
56	.0089	101	.0411	146	.0911	191	.1411
57	.0078	102	.0422	147	.0922	192	.1422
58	.0067	103	.0433	148	.0933	193	.1433
59	.0056	104	.0444	149	.0944	194	.1444
60	.0044	105	.0456	150	+ .0956	195	.1456
61	− .0033	106	+ .0467	151	.0967	196	+ .1467
62	.0022	107	.0478	152	.0978	197	.1478
63	.0011	108	.0489	153	.0989	198	.1489
64	.0000	109	.0500	154	.1000	199	.1500

TABLE XVII.—CORRECTION FOR EARTH'S CURVATURE AND REFRACTION

L°	H°	L°	H°	L°	H°	L°	H°	L°	H°	Miles	H°
300	.002	1300	.035	2300	.108	3300	.223	4300	.379	1	.571
400	.003	1400	.040	2400	.118	3400	.237	4400	.397	2	2.285
500	.005	1500	.046	2500	128	3500	.251	4500	.415	3	5.142
600	007	1600	.052	2600	.139	3600	.266	4600	.434	4	9.141
700	.010	1700	.059	2700	.149	3700	.281	4700	.453	5	14.283
800	.013	1800	.066	2800	.161	3800	.296	4800	.472	6	20.567
900	.017	1900	.074	2900	.172	3900	.312	4900	.492	7	27.994
[illegible]	020	2000	082	3000	.184	4000	.328	5000	.512	8	36.563
	.025	2100	.090	3100	.197	4100	.345	5100	.533	9	46.275
	.030	2200	.099	3200	.210	4200	.362	5200	.554	10	57.130

ABLE XVIII.—STADIA REDUCTIONS FOR READING 100

DIFFERENCES IN ELEVATION

Minutes.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0	.00	1.74	3.49	5.23	6.96	8.68	10.40	12.10	13.78	15.45
2	.06	1.80	3.55	5.28	7.02	8.74	10.45	12.15	13.84	15.51
4	.12	1.86	3.60	5.34	7.07	8.80	10.51	12.21	13.89	15.56
6	.17	1.92	3.66	5.40	7.13	8.85	10.57	12.26	13.95	15.62
8	.23	1.98	3.72	5.46	7.19	8.91	10.62	12.32	14.01	15.67
10	.29	2.04	3.78	5.52	7.25	8.97	10.68	12.38	14.06	15.73
12	.35	2.09	3.84	5.57	7.30	9.03	10.74	12.43	14.12	15.78
14	.41	2.15	3.90	5.63	7.36	9.08	10.79	12.49	14.17	15.84
16	.47	2.21	3.95	5.69	7.42	9.14	10.85	12.55	14.23	15.89
18	.52	2.27	4.01	5.75	7.48	9.20	10.91	12.60	14.28	15.95
20	.58	2.33	4.07	5.80	7.53	9.25	10.96	12.66	14.34	16.00
22	.64	2.38	4.13	5.86	7.59	9.31	11.02	12.72	14.40	16.06
24	.70	2.44	4.18	5.92	7.65	9.37	11.08	12.77	14.45	16.11
26	.76	2.50	4.24	5.98	7.71	9.43	11.13	12.83	14.51	16.17
28	.81	2.56	4.30	6.04	7.76	9.48	11.19	12.88	14.56	16.22
30	.87	2.62	4.36	6.09	7.82	9.54	11.25	12.94	14.62	16.28
32	.93	2.67	4.42	6.15	7.88	9.60	11.30	13.00	14.67	16.33
34	.99	2.73	4.48	6.21	7.94	9.65	11.36	13.05	14.73	16.39
36	1.05	2.79	4.53	6.27	7.99	9.71	11.42	13.11	14.79	16.44
38	1.11	2.85	4.59	6.33	8.05	9.77	11.47	13.17	14.84	16.50
40	1.16	2.91	4.65	6.38	8.11	9.83	11.53	13.22	14.90	16.55
42	1.22	2.97	4.71	6.44	8.17	9.88	11.59	13.28	14.95	16.61
44	1.28	3.02	4.76	6.50	8.22	9.94	11.64	13.33	15.01	16.66
46	1.34	3.08	4.82	6.56	8.28	10.00	11.70	13.39	15.06	16.72
48	1.40	3.14	4.88	6.61	8.34	10.05	11.76	13.45	15.12	16.77
50	1.45	3.20	4.94	6.67	8.40	10.11	11.81	13.50	15.17	16.83
52	1.51	3.26	4.99	6.73	8.45	10.17	11.87	13.56	15.23	16.88
54	1.57	3.31	5.05	6.78	8.51	10.22	11.93	13.61	15.28	16.94
56	1.63	3.37	5.11	6.84	8.57	10.28	11.98	13.67	15.34	16.99
58	1.69	3.43	5.17	6.90	8.63	10.34	12.04	13.73	15.40	17.05
60	1.74	3.49	5.23	6.96	8.68	10.40	12.10	13.78	15.45	17.10
$f+c$										
.75	.01	.02	.03	.05	.06	.07	.08	.10	.11	.12
1.00	.01	.03	.04	.06	.08	.09	.11	.13	.15	.16
1.25	.02	.03	05	.08	.10	.11	.14	.16	.18	.21

CORRECTIONS TO HORIZONTAL DISTANCES

Vertical Angle.	0′	10′	20′	30′	40′	50′	Vertical Angle.
0°	....	....	....	.01	.01	.02	0°
1	.03	.04	.05	.07	.08	.10	1
2	.12	.14	.17	.19	.22	.24	2
3	.27	.31	.34	.37	.41	45	3
4	.49	.53	.57	.62	.66	.71	4
5	.76	.81	.86	.92	.98	1.03	5
6	1.09	1.15	1.22	1.28	1.35	1.42	6
7	1.49	1.56	1.63	1.70	1.78	1.86	7
8	1.94	2.02	2.10	2.18	2.27	2.36	8
9	2.45	2.54	2.63	2.72	2.82	2.92	9

TABLE XVIII.—STADIA REDUCTIONS FOR READING 100

DIFFERENCES IN ELEVATION

Minutes.	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°
0	17.10	18.73	20.34	21.92	23.47	25.00	26.50	27.96	29.39	30.78
2	17.16	18.78	20.39	21.97	23.52	25.05	26.55	28.01	29.44	30.83
4	17.21	18.84	20.44	22.02	23.58	25.10	26.59	28.06	29.48	30.87
6	17.26	18.89	20.50	22.08	23.63	25.15	26.64	28.10	29.53	30.92
8	17.32	18.95	20.55	22.13	23.68	25.20	26.69	28.15	29.58	30.97
10	17.37	19.00	20.60	22.18	23.73	25.25	26.74	28.20	29.62	31.01
12	17.43	19.05	20.66	22.23	23.78	25.30	26.79	28.25	29.67	31.06
14	17.48	19.11	20.71	22.28	23.83	25.35	26.84	28.30	29.72	31.10
16	17.54	19.16	20.76	22.34	23.88	25.40	26.89	28.34	29.76	31.15
18	17.59	19.21	20.81	22.39	23.93	25.45	26.94	28.39	29.81	31.19
20	17.65	19.27	20.87	22.44	23.99	25.50	26.99	28.44	29.86	31.24
22	17.70	19.32	20.92	22.49	24.04	25.55	27.04	28.49	29.90	31.28
24	17.76	19.38	20.97	22.54	24.09	25.60	27.09	28.54	29.95	31.32
26	17.81	19.43	21.03	22.60	24.14	25.65	27.13	28.58	30.00	31.38
28	17.86	19.48	21.08	22.65	24.19	25.70	27.18	28.63	30.04	31.42
30	17.92	19.54	21.13	22.70	24.24	25.75	27.23	28.68	30.09	31.47
32	17.97	19.59	21.18	22.75	24.29	25.80	27.28	28.73	30.14	31.51
34	18.03	19.64	21.24	22.80	24.34	25.85	27.33	28.77	30.19	31.56
36	18.08	19.70	21.29	22.85	24.39	25.90	27.38	28.82	30.23	31.60
38	18.14	19.75	21.34	22.91	24.44	25.95	27.43	28.87	30.28	31.65
40	18.19	19.80	21.39	22.96	24.49	26.00	27.48	28.92	30.32	31.69
42	18.24	19.86	21.45	23.01	24.55	26.05	27.52	28.96	30.37	31.74
44	18.30	19.91	21.50	23.06	24.60	26.10	27.57	29.01	30.41	31.78
46	18.35	19.96	21.55	23.11	24.65	26.15	27.62	29.06	30.46	31.83
48	18.41	20.02	21.60	23.16	24.70	26.20	27.67	29.11	30.51	31.87
50	18.46	20.07	21.66	23.22	24.75	26.25	27.72	29.15	30.55	31.92
52	18.51	20.12	21.71	23.27	24.80	26.30	27.77	29.20	30.60	31.96
54	18.57	20.18	21.76	23.32	24.85	26.35	27.81	29.25	30.65	32.01
56	18.62	20.23	21.81	23.37	24.90	26.40	27.86	29.30	30.69	32.05
58	18.68	20.28	21.87	23.42	24.95	26.45	27.91	29.34	30.74	32.09
60	18.73	20.34	21.92	23.47	25.00	26.50	27.96	29.39	30.78	32.14
$f+r$										
.75	.14	.15	.16	.17	.19	.20	.21	.23	.24	.25
1.00	.18	.20	.22	.23	.25	.27	.28	.30	.32	.33
1.25	.23	.25	.27	.29	.31	.34	.36	.38	.40	.42

CORRECTIONS TO HORIZONTAL DISTANCES

Vertical Angle.	0′	10′	20′	30′	40′	50′	Vertical Angle.
10°	3.02	3.12	3.22	3.32	3.43	3.53	10°
11	3.64	3.75	3.86	3.97	4.09	4.21	11
12	4.32	4.44	4.56	4.68	4.81	4.93	12
13	5.06	5.19	5.32	5.45	5.58	5.72	13
14	5.85	5.99	6.13	6.27	6.41	6.55	14
15	6.70	6.84	6.99	7.14	7.29	7.44	15
16	7.60	7.75	7.91	8.07	8.23	8.39	16
17	8.55	8.71	8.88	9.04	9.21	9.38	17
18	9.55	9.72	9.89	10.07	10.24	10.42	18
19	10.60	10.78	10.96	11.14	11.33	11.51	19

ABLE XVIII.—STADIA REDUCTIONS FOR READING 100

DIFFERENCES IN ELEVATION

Minutes.	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°
0	32.14	33.46	34.73	35.97	37.16	38.30	39.40	40.45	41.45	42.40
2	32.18	33.50	34.77	36.01	37.20	38.34	39.44	40.49	41.48	42.43
4	32.23	33.54	34.82	36.05	37.23	38.38	39.47	40.52	41.52	42.46
6	32.27	33.59	34.86	36.09	37.27	38.41	39.51	40.55	41.55	42.49
8	32.32	33.63	34.90	36.13	37.31	38.45	39.54	40.59	41.58	42.53
10	32.36	33.67	34.94	36.17	37.35	38.49	39.58	40.62	41.61	42.56
12	32.41	33.72	34.98	36.21	37.39	38.53	39.61	40.66	41.65	42.59
14	32.45	33.76	35.02	36.25	37.43	38.56	39.65	40.69	41.68	42.62
16	32.49	33.80	35.07	36.29	37.47	38.60	39.69	40.72	41.71	42.65
18	32.54	33.84	35.11	36.33	37.51	38.64	39.72	40.76	41.74	42.68
20	32.58	33.89	35.15	36.37	37.54	38.67	39.76	40.79	41.77	42.71
22	32.63	33.93	35.19	36.41	37.58	38.71	39.79	40.82	41.81	42.74
24	32.67	33.97	35.23	36.45	37.62	38.75	39.83	40.86	41.84	42.77
26	32.72	34.01	35.27	36.49	37.66	38.78	39.86	40.89	41.87	42.80
28	32.76	34.06	35.31	36.53	37.70	38.82	39.90	40.92	41.90	42.83
30	32.80	34.10	35.36	36.57	37.74	38.86	39.93	40.96	41.93	42.86
32	32.85	34.14	35.40	36.61	37.77	38.89	39.97	40.99	41.97	42.89
34	32.89	34.18	35.44	36.65	37.81	38.93	40.00	41.02	42.00	42.92
36	32.93	34.23	35.48	36.69	37.85	38.97	40.04	41.06	42.03	42.95
38	32.98	34.27	35.52	36.73	37.89	39.00	40.07	41.09	42.06	42.98
40	33.02	34.31	35.56	36.77	37.93	39.04	40.11	41.12	42.09	43.01
42	33.07	34.35	35.60	36.80	37.96	39.08	40.14	41.16	42.12	43.04
44	33.11	34.40	35.64	36.84	38.00	39.11	40.18	41.19	42.15	43.07
46	33.15	34.44	35.68	36.88	38.04	39.15	40.21	41.22	42.19	43.10
48	33.20	34.48	35.72	36.92	38.08	39.18	40.24	41.26	42.22	43.13
50	33.24	34.52	35.76	36.96	38.11	39.22	40.28	41.29	42.25	43.16
52	33.28	34.57	35.80	37.00	38.15	39.26	40.31	41.32	42.28	43.18
54	33.33	34.61	35.85	37.04	38.19	39.29	40.35	41.35	42.31	43.21
56	33.37	34.65	35.89	37.08	38.23	39.33	40.38	41.39	42.34	43.24
58	33.41	34.69	35.93	37.12	38.26	39.36	40.42	41.42	42.37	43.27
60	33.46	34.73	35.97	37.16	38.30	39.40	40.45	41.45	42.40	43.30
$f+c$										
.75	.26	.27	.29	.30	.31	.32	.33	.35	.36	.37
1.00	.35	.37	.38	.40	.41	.43	.45	.46	.47	.48
1.25	.44	.46	.48	.50	.52	.54	.56	.58	.60	.62

CORRECTIONS TO HORIZONTAL DISTANCES

Vertical Angle.	0′	10′	20′	30′	40′	50′	Vertical Angle.
20°	11.70	11.89	12.07	12.26	12.46	12.65	20°
21	12.84	13.04	13.23	13.43	13.63	13.83	21
22	14.03	14.24	14.44	14.64	14.85	15.06	22
23	15.27	15.48	15.69	15.90	16.11	16.33	23
24	16.54	16.76	16.98	17.20	17.42	17.64	24
25	17.86	18.08	18.31	18.53	18.76	18.99	25
26	19.22	19.45	19.68	19.91	20.14	20.38	26
27	20.61	20.85	21.08	21.32	21.56	21.80	27
28	22.04	22.28	22.52	22.77	23.01	23.26	28
29	23.50	23.75	24.00	24.25	24.50	24.75	29

Latitude.	Hour Angle.	DECLINATIONS.								
		+20°	+15°	+10°	+5°	+0°	−5°	−10°	−15°	−20°
2° 30′	0 h	−18″	−12″	−07″	−02″	02″	07″	12″	18″	23″
	2	−18	−12	−07	−02	02	07	12	18	23
	3	−17	−11	−06	−01	03	08	13	19	25
	4	−15	−10	−05	00	05	10	15	21	27
	5	−10	−05	00	+05	10	15	20	26	32
5°	0 h	−15″	−10″	−05″	00″	05″	10″	15″	20″	27″
	2	−15	−10	−05	00	05	10	15	20	27
	3	−13	−08	−03	+02	07	12	17	23	29
	4	−10	−05	00	+05	10	15	20	27	32
	5	−05	00	+05	+10	15	20	27	32	40
7° 30′	0 h	−13″	−08″	−02″	02″	08″	13″	18″	24″	29″
	2	−12	−07	−01	03	09	14	19	25	31
	3	−10	−05	00	05	10	15	20	26	32
	4	−05	00	+05	10	15	20	26	32	39
	5	+07	+12	+17	23	29	36	43	51	1′ 01
10°	0 h	−10″	−05″	00″	05″	10″	15″	20″	26″	32″
	2	−07	−03	02	07	12	17	22	28	34
	3	−05	00	03	08	13	19	25	31	38
	4	00	+05	10	15	20	26	32	39	46
	5	+15	+20	26	32	39	46	55	1′ 06	1′ 19
12° 30′	0 h	−08″	−02″	02″	08″	13″	18″	24″	30″	36″
	2	−06	00	05	10	15	20	26	32	39
	3	+02	+07	12	17	23	29	36	43	51
	4	+04	+09	14	20	25	31	40	48	55
	5	+21	+27	33	40	48	57	1′ 08	1′ 23	1′ 41
15°	0 h	−05″	00″	05″	10″	15″	21″	27″	33″	40″
	2	−03	02	07	12	18	23	29	36	43
	3	+01	05	11	16	22	28	34	41	49
	4	+08	12	19	24	30	37	44	53	1′ 04
	5	+29	34	41	49	59	1′ 10	1′ 24	1′ 43	2 08
17° 30′	0 h	−02″	02″	08″	13″	18″	24″	30″	36″	44″
	2	00	05	10	15	21	27	33	40	48
	3	+02	10	15	21	27	33	40	48	57
	4	+13	18	23	29	35	43	51	1′ 01	1′ 13
	5	+34	41	49	58	1′ 10	1′ 23	1′ 41	2 06	2 42
20°	0 h	00″	05″	10″	15″	21″	27″	33″	40″	48″
	2	03	07	13	18	24	30	36	44	52
	3	06	13	18	24	30	36	44	52	1′ 02
	4	17	22	28	35	42	50	1′ 00	1′ 11	1 26
	5	39	47	57	1′ 07	1′ 20	1′ 37	2 00	2 32	3 25
22° 30′	0 h	02″	08″	13″	18″	24″	30″	36″	44″	52″
	2	06	11	15	21	27	33	40	48	57
	3	11	15	21	27	33	40	48	57	1′ 08
	4	20	26	32	39	46	56	1′ 07	1′ 19	1 37
	5	45	53	1′ 03	1′ 16	1′ 31	1′ 52	2 21	3 07	4 28
25°	0 h	05″	10″	15″	21″	27″	33″	40″	48″	57″
	2	08	14	19	25	31	38	46	54	1′ 05
	3	12	18	24	30	37	44	53	04	1 18
	4	23	29	35	45	53	1′ 03	1′ 16	1 31	1 52
	5	49	59	1′ 10	1′ 24	1′ 52	2 07	2 44	3 46	5 43
		+20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°

TABLE XIX.—MEAN REFRACTIONS IN DECLINATION

Latitude	Hour Angle	DECLINATIONS.								
		+20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°
27° 30′	0 h	08″	13″	18″	24″	30″	36″	44″	52″	1′ 02″
	2	11	16	22	28	34	41	49	1′ 00	1 10
	3	17	22	28	35	42	50	1′ 00	1 11	1 26
	4	28	35	42	50	1′ 00	1′ 11	1 26	1 43	2 09
	5	54	1′ 05	1′ 18	1′ 34	1 54	2 24	3 11	4 38	8 15
30°	0 h	10″	15″	21″	27″	33″	40″	48″	57″	1′ 08″
	2	14	19	25	31	38	46	54	1′ 05	1 18
	3	20	26	32	39	47	55	1′ 06	1 19	1 36
	4	32	39	46	52	1′ 06	1′ 19	1 35	1 57	2 29
	5	1′ 00	1′ 10	1′ 24	1′ 52	2 07	2 44	3 46	5 43	13 06
32° 30′	0 h	13″	18″	24″	30″	36″	44″	52″	1′ 02″	1′ 14″
	2	17	22	28	35	42	50	1′ 00	1 11	1 26
	3	23	29	35	43	51	1′ 01	1 13	1 28	1 47
	4	35	43	51	1′ 01	1′ 13	1 27	1 46	2 13	2 54
	5	1′ 03	1′ 15	1′ 31	1 53	2 20	3 05	4 25	7 36	
35°	0 h	15″	21″	27″	33″	40″	48″	57″	1′ 08″	1′ 21″
	2	20	25	32	38	46	55	1′ 05	1 18	1 35
	3	26	33	39	47	56	1′ 07	1 21	1 38	2 00
	4	39	47	56	1′ 07	1′ 20	1 36	1 59	2 32	3 25
	5	1′ 07	1′ 20	1′ 38	2 00	2 34	3 29	5 14	10 16	
37° 30′	0 h	18″	24″	30″	36″	44″	52″	1′ 02″	1′ 14″	1′ 29″
	2	22	28	35	42	50	1′ 00	1 12	1 26	1 45
	3	29	36	43	52	1′ 02	1 14	1 29	1 49	2 16
	4	43	51	1′ 01	1′ 13	1 27	1 49	2 14	2 54	4 05
	5	1′ 11	1′ 26	1 54	2 10	2 49	3 55	6 15	14 58	
40°	0 h	21″	27″	33″	40″	48″	57″	1′ 08″	1′ 21″	1′ 39″
	2	25	32	39	46	52	1′ 06	1 19	1 35	1 57
	3	33	40	48	57	1′ 08	1 21	1 38	2 02	2 36
	4	47	55	1′ 06	1′ 19	1 36	1 58	2 30	3 21	4 59
	5	1′ 15	1′ 31	1 51	2 20	3 05	4 25	7 34	25 18	
42° 30′	0 h	24″	30″	36″	44″	52″	1′ 02″	1′ 14″	1′ 29″	1′ 49″
	2	28	35	39	50	1′ 00	1 12	1 26	1 45	2 11
	3	36	43	52	1′ 02	1 13	1 29	1 49	2 17	2 59
	4	50	1′ 00	1′ 11	1 26	1 44	2 10	2 49	3 55	6 16
	5	1′ 19	1 36	1 58	2 30	3 22	5 00	9 24		
45°	0 h	27″	33″	40″	48″	57″	1′ 08″	1′ 21″	1′ 39″	2′ 02″
	2	32	39	46	52	1′ 06	1 19	1 35	1 57	2 29
	3	40	47	56	1′ 07	1 21	1 38	2 00	2 34	3 29
	4	54	1′ 04	1′ 16	1 33	1 54	2 24	3 11	4 38	8 15
	5	1′ 23	1 41	2 05	2 41	3 40	5 40	12 02		
47° 30′	0 h	30″	36″	44″	52″	1′ 02″	1′ 14″	1′ 29″	1′ 49″	2′ 18″
	2	35	42	50	1′ 00	1 12	1 26	1 45	2 01	2 51
	3	43	51	1′ 01	1 13	1 28	1 47	2 15	2 56	4 08
	4	56	1′ 09	1 23	1 40	2 05	2 40	3 39	5 37	11 18
	5	1′ 27	1 46	2 12	2 52	4 01	6 30	16 19		
		+20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°

TABLE XIX.—MEAN REFRACTIONS IN DECLINATION

Latitude.	Hour Angle.	DECLINATIONS. +20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°
50°	0 h	33″	40″	48″	57″	1′ 08″	1′ 21″	1′ 39″	2′ 02″	2′ 36″
	2	38	46	55	1′ 06	1 18	1 35	1 57	2 28	3 19
	3	47	56	1′ 06	1 19	1 36	2 29	2 31	3 23	5 02
	4	1′ 02	1′ 14	1 29	1 48	2 16	2 58	4 18	6 59	19 47
	5	1 30	1 51	2 19	3 04	4 22	7 28	24 10		
52° 30′	0 h	36″	44″	52″	1′ 02″	1′ 14″	1′ 29″	1′ 49″	2′ 18″	3′ 05″
	2	43	50	59	1 11	1 26	1 42	2 23	2 49	3 55
	3	50	1′ 00	1′ 11	1 26	1 45	2 11	2 51	2 58	6 22
	4	1′ 05	1 18	1 35	2 10	2 28	3 19	4 53	8 42	
	5	1 34	1 56	2 27	3 16	4 47	8 52			
55°	0 h	40″	48″	57″	1′ 08″	1′ 21″	1′ 39″	2′ 02″	2′ 36″	3′ 33″
	2	46	55	1′ 05	1 18	1 34	1 56	2 30	3 15	4 47
	3	55	1′ 06	1 19	1 35	1 58	2 30	3 21	4 58	9 19
	4	1′ 10	1 23	1 42	2 06	2 43	3 44	5 49	13 41	
	5	1 37	2 01	2 34	3 28	5 15	10 18			
57° 30′	0 h	44″	52″	1′ 02″	1′ 14″	1′ 29″	1′ 49″	2′ 18″	3′ 05″	4′ 37″
	2	50	59	1 11	1 25	1 43	2 09	2 47	3 51	6 04
	3	58	1′ 10	1 24	1 42	2 07	2 43	3 45	5 50	12 47
	4	1′ 11	1 25	1 43	2 10	2 50	3 55	6 14	14 49	
	5	1 41	2 06	2 42	3 42	5 46	12 26			
60°	0 h	48″	57″	1′ 08″	1′ 21″	1′ 39″	2′ 02″	2′ 36″	3′ 33″	5′ 23″
	2	54	1′ 04	1 17	1 33	1 54	2 24	3 12	4 38	8 15
	3	1′ 03	1 15	1 30	1 51	2 20	3 04	4 24	7 31	24 44
	4	1 18	1 34	1 56	2 28	3 18	4 50	8 53		
	5	1 45	2 11	2 50	3 57	6 21	15 32			
62° 30′	0 h	52″	1′ 02″	1′ 14″	1′ 29″	1′ 50	2′ 18″	3′ 00″	4′ 17″	7′ 13″
	2	58	1 09	1 23	1 41	2 06	2 43	3 44	5 50	12 44
	3	1′ 07	1 23	1 38	2 01	2 35	3 30	5 16	10 24	
	4	1 23	1 40	2 05	2 40	3 40	5 37	11 50		
	5	1 48	2 17	2 59	4 14	7 03				
65°	0 h	57″	1′ 08″	1′ 21″	1′ 39″	2′ 02″	2′ 36″	3′ 33″	5′ 23″	10′ 51″
	2	1′ 03	1 16	1 31	1 52	2 21	3 07	4 28	7 44	
	3	1 12	1 27	1 46	2 12	2 52	4 02	6 33		
	4	1 27	1 47	2 13	2 54	4 05	6 40			
	5	1 52	2 22	3 08	4 30	7 52				
67° 30′	0 h	1′ 02″	1′ 14″	1′ 29″	1′ 50″	2′ 18″	3′ 00″	4′ 17″	7′ 13″	
	2	1 08	1 22	1 40	2 03	2 39	3 37	5 32	11 28	
	3	1 17	1 34	1 55	2 26	3 14	4 44	8 34		
	4	1 32	1 53	2 23	3 14	4 35	8 05			
	5	1 56	2 28	3 17	4 40	8 51				
70°	0 h	1′ 08″	1′ 21″	1′ 39″	2′ 02″	2′ 36″	3′ 33″	5′ 23″	10′ 51″	
	2	1 14	1 29	1 50	2 18	3 00	4 17	7 13		
	3	1 23	1 43	2 05	2 41	3 41	5 59	12 15		
	4	1 37	2 00	2 34	3 28	5 20	10 12			
	5	2 02	2 33	3 27	5 11	10 05				
		+20°	+15°	+10°	+5°	0°	−5°	−10°	−15°	−20°

Sec.	Length.	Min.	Length.	Deg.	Length.	Deg.	Length.
1	.0000048	1	.0002909	1	.0174533	61	1.0646508
2	.0000097	2	.0005818	2	.0349066	62	1.0821041
3	.0000145	3	.0008727	3	.0523599	63	1.0995574
4	.0000194	4	.0011636	4	.0698132	64	1.1170107
5	.0000242	5	.0014544	5	.0872665	65	1.1344640
6	.0000291	6	.0017453	6	.1047198	66	1.1519173
7	.0000339	7	.0020362	7	.1221730	67	1.1693706
8	.0000388	8	.0023271	8	.1396263	68	1.1868239
9	.0000436	9	.0026180	9	.1570796	69	1.2042772
10	.0000485	10	.0029089	10	.1745329	70	1.2217305
11	.0000533	11	.0031998	11	.1919862	71	1.2391838
12	.0000582	12	.0034907	12	.2094395	72	1.2566371
13	.0000630	13	.0037815	13	.2268928	73	1.2740904
14	.0000679	14	.0040724	14	.2443461	74	1.2915436
15	.0000727	15	.0043633	15	.2617994	75	1.3089969
16	.0000776	16	.0046542	16	.2792527	76	1.3264502
17	.0000824	17	.0049451	17	.2967060	77	1.3439035
18	.0000873	18	.0052360	18	.3141593	78	1.3613568
19	.0000921	19	.0055269	19	.3316126	79	1.3788101
20	.0000970	20	.0058178	20	.3490659	80	1.3962634
21	.0001018	21	.0061087	21	.3665191	81	1.4137167
22	.0001067	22	.0063995	22	.3839724	82	1.4311700
23	.0001115	23	.0066904	23	.4014257	83	1.4486233
24	.0001164	24	.0069813	24	.4188790	84	1.4660766
25	.0001212	25	.0072722	25	.4363323	85	1.4835299
26	.0001261	26	.0075631	26	.4537856	86	1.5009832
27	.0001309	27	.0078540	27	.4712389	87	1.5184364
28	.0001357	28	.0081449	28	.4886922	88	1.5358897
29	.0001406	29	.0084358	29	.5061455	89	1.5533430
30	.0001454	30	.0087266	30	.5235988	90	1.5707963
31	.0001503	31	.0090175	31	.5410521	91	1.5882496
32	.0001551	32	.0093084	32	.5585054	92	1.6057029
33	.0001600	33	.0095993	33	.5759587	93	1.6231562
34	.0001648	34	.0098902	34	.5934119	94	1.6406095
35	.0001697	35	.0101811	35	.6108652	95	1.6580628
36	.0001745	36	.0104720	36	.6283185	96	1.6755161
37	.0001794	37	.0107629	37	.6457718	97	1.6929694
38	.0001842	38	.0110538	38	.6632251	98	1.7104227
39	.0001891	39	.0113446	39	.6806784	99	1.7278760
40	.0001939	40	.0116355	40	.6981317	100	1.7453293
41	.0001988	41	.0119264	41	.7155850	101	1.7627825
42	.0002036	42	.0122173	42	.7330383	102	1.7802358
43	.0002085	43	.0125082	43	.7504916	103	1.7976891
44	.0002133	44	.0127991	44	.7679449	104	1.8151424
45	.0002182	45	.0130900	45	.7853982	105	1.8325957
46	.0002230	46	.0133809	46	.8028515	106	1.8500490
47	.0002279	47	.0136717	47	.8203047	107	1.8675023
48	.0002327	48	.0139626	48	.8377580	108	1.8849556
49	.0002376	49	.0142535	49	.8552113	109	1.9024089
50	.0002424	50	.0145444	50	.8726646	110	1.9198622
51	.0002473	51	.0148353	51	.8901179	111	1.9373155
52	.0002521	52	.0151262	52	.9075712	112	1.9547688
53	.0002570	53	.0154171	53	.9250245	113	1.9722221
54	.0002618	54	.0157080	54	.9424778	114	1.9896753
55	.0002666	55	.0159989	55	.9599311	115	2.0071286
56	.0002715	56	.0162897	56	.9773844	116	2.0245819
57	.0002763	57	.0165806	57	.9948377	117	2.0420352
58	.0002812	58	.0168715	58	1.0122910	118	2.0594885
59	.0002860	59	.0171624	59	1.0297443	119	2.0769418
60	.0002909	60	.0174533	60	1.0471976	120	2.0943951

TABLE XXI.—MINUTES IN DECIMALS OF A DEGREE

′	0″	10″	15″	20″	30″	40″	45″	50″	′
0	.00000	00278	.00417	.00556	.00833	.01111	.01250	.01389	0
1	.01667	.01944	.02083	.02222	.02500	02778	.02917	.03055	1
2	.03333	.03611	.03750	.03889	.04167	.04444	.04583	.04722	2
3	.05000	.05278	.05417	.05556	.05833	.06111	.06250	.06389	3
4	.06667	.06944	.07083	.07222	.07500	.07778	.07917	.08056	4
5	.08333	.08611	.08750	.08889	.09167	.09444	.09583	.09722	5
6	.10000	.10278	.10417	.10556	.10833	.11111	.11250	.11389	6
7	.11667	.11944	.12083	.12222	.12500	.12778	.12917	.13056	7
8	.13333	.13611	.13750	.13889	.14167	.14444	.14583	.14722	8
9	.15000	.15278	.15417	.15556	.15833	.16111	.16250	.16389	9
10	.16667	.16944	.17083	.17222	.17500	.17778	.17917	.18056	10
11	.18333	.18611	.18750	.18889	.19167	19444	.19583	.19722	11
12	.20000	.20278	.20417	.20556	.20833	.21111	.21250	.21389	12
13	.21667	.21944	.22083	.22222	.22500	.22778	.22917	.23056	13
14	.23333	.23611	.23750	.23889	.24167	.24444	.24583	.24722	14
15	.25000	.25278	.25417	.25556	.25833	.26111	.26250	.26389	15
16	.26667	.26944	.27083	.27222	.27500	.27778	.27917	.28056	16
17	.28333	.28611	.28750	.28889	.29167	.29444	.29583	.29722	17
18	.30000	.30278	.30417	.30556	.30833	.31111	.31250	.31389	18
19	.31667	.31944	.32083	.32222	.32500	.32778	.32917	.33056	19
20	.33333	.33611	.33750	.33889	.34167	.34444	.34583	.34722	20
21	.35000	.35278	.35417	.35556	.35833	.36111	.36250	.36389	21
22	.36667	.36944	.37083	.37222	.37500	.37778	.37917	.38056	22
23	.38333	.38611	.38750	.38889	.39167	.39444	.39583	.39722	23
24	.40000	.40278	.40417	.40556	.40833	.41111	.41250	.41389	24
25	.41667	.41944	.42083	.42222	.42500	.42778	.42917	.43056	25
26	.43333	.43611	.43750	.43889	.44167	.44444	.44583	.44722	26
27	.45000	.45278	.45417	.45556	.45833	.46111	.46250	.46389	27
28	.46667	.46944	.47083	.47222	.47500	.47778	.47917	.48056	28
29	.48333	.48611	.48750	.48889	.49167	.49444	.49583	.49722	29
30	.50000	.50278	.50417	.50556	.50833	.51111	.51250	.51389	30
31	.51667	.51944	.52083	.52222	.52500	.52778	.52917	.53056	31
32	.53333	.53611	.53750	.53889	.54167	.54444	.54583	.54722	32
33	.55000	.55278	.55417	.55556	.55833	.56111	.56250	.56389	33
34	.56667	.56944	.57083	.57222	.57500	.57778	.57917	.58056	34
35	.58333	.58611	.58750	.58889	.59167	.59444	.59583	.59722	35
36	.60000	.60278	.60417	.60556	.60833	.61111	.61250	.61389	36
37	.61667	.61944	.62083	.62222	.62500	.62778	.62917	.63056	37
38	.63333	.63611	.63750	.63889	.64167	.64444	.64583	.64722	38
39	.65000	.65278	.65417	.65556	.65833	.66111	.66250	.66389	39
40	.66667	.66944	.67083	.67222	.67500	.67778	.67917	.68056	40
41	.68333	.68611	.68750	.68889	.69167	.69444	.69583	.69722	41
42	.70000	.70278	.70417	.70556	.70833	.71111	.71250	.71389	42
43	.71667	.71944	.72083	.72222	.72500	.72778	.72917	.73056	43
44	.73333	.73611	.73750	.73889	.74167	.74444	.74583	.74722	44
45	.75000	.75278	.75417	.75556	.75833	.76111	.76250	.76389	45
46	.76667	.76944	.77083	.77222	.77500	.77778	.77917	.78056	46
47	.78333	.78611	.78750	.78889	.79167	.79444	.79583	.79722	47
48	.80000	.80278	.80417	.80556	.80833	.81111	.81250	.81389	48
49	.81667	.81944	.82083	.82222	.82500	.82778	.82917	.83056	49
50	.83333	.83611	.83750	.83889	.84167	.84444	.84583	.84722	50
51	.85000	.85278	.85417	.85556	.85833	86111	.86250	.86389	51
52	.86667	.86944	.87083	.87222	.87500	.87778	.87917	.88056	52
53	.88333	.88611	.88750	.88889	.89167	.89444	.89583	.89722	53
54	.90000	.90278	.90417	.90556	.90833	.91111	.91250	.91389	54
55	.91667	.91944	.92083	.92222	.92500	.92778	.92917	.93056	55
56	.93333	.93611	.93750	.93889	.94167	.94444	.94583	.94722	56
57	.95000	.95278	.95417	.95556	.95833	.96111	.96250	.96389	57
58	.96667	.96944	.97085	.97222	.97500	.97778	.97917	.98056	58
59	*.98333*	*.98611*	.98750	.98889	.99167	.99444	.99583	.99722	59
′	*0″*	*10″*	15″	20″	30″	40″	45″	50″	′

BLE XXII.—TURNOUTS AND SWITCHES FROM A STRAIGHT TRACK

Gauge, 4 Feet 8½ Inches = 4.708. Throw, 5 Inches = 0.417.

	Angle *F.*	Dist. *BF.*	Chord *af.*	Switch *AD.*	Radius *r.*	Log'thm. *log. r.*	Degree of Curve.
	14° 15′ 00″	37.664	37.373	11.209	150.656	2.177986	38° 45′ 57″
½	12 40 49	42.372	42.113	12.610	190.674	2.280292	30 24 09
	11 25 16	47.080	46.846	14.012	235.400	2.371806	24 31 36
½	10 23 20	51.788	51.575	15.413	284.834	2.454592	20 13 13
	9 31 39	56.496	56.301	16.814	338.976	2.530169	16 57 52
½	8 47 51	61.204	61.024	18.215	397.826	2.599693	14 26 25
	8 10 16	65.912	65.744	19.616	461.384	2.664063	12 26 34
½	7 37 41	70.620	70.464	21.017	529.650	2.723989	10 50 02
	7 09 10	75.328	75.181	22.418	602.624	2.780046	9 31 07
½	6 43 59	80.036	79.898	23.820	680.306	2.832704	8 25 47
	6 21 35	84.744	84.618	25.221	762.696	2.882352	7 31 04
½	6 01 32	89.452	89.328	26.622	849.794	2.929314	6 44 46
	5 43 29	94.160	94.043	28.023	941.600	2.973866	6 05 16
½	5 27 09	98.868	98.756	29.424	1038.114	3.016245	5 31 17
	5 12 18	103.576	103.469	30.825	1139.336	3.056652	5 01 50
½	4 58 45	108.284	108.182	32.227	1245.266	3.095262	4 36 08
	4 46 19	112.992	112.894	33.628	1355.904	3.132229	4 13 36

Gauge, 3 Feet. Throw, 4 Inches = 0.333.

	Angle *F.*	Dist. *BF.*	Chord *af.*	Switch *AD.*	Radius *r.*	Log'thm. *log. r.*	Degree of Curve.
	14° 15′ 00″	24	23.815	8	96.0	1.982271	62° 46′ 34″
½	12 40 49	27	26.835	9	121.5	2.084576	48 36 04
	11 25 16	30	29.851	10	150.0	2.176091	38 56 33
½	10 23 20	33	32.865	11	181.5	2.258877	31 58 55
	9 31 39	36	35.876	12	216.0	2.334454	26 46 07
½	8 47 51	39	38.885	13	253.5	2.403978	22 45 04
	8 10 16	42	41.893	14	294.0	2.468347	19 35 01
½	7 37 41	45	44.900	15	337.5	2.528274	17 02 21
	7 09 10	48	47.906	16	384.0	2.584331	14 57 48
½	6 43 59	51	50.912	17	433.5	2.636989	13 14 47
	6 21 35	54	53.917	18	486.0	2.686636	11 48 37
½	6 01 32	57	56.921	19	541.5	2.733598	10 35 46
	5 43 29	60	59.925	20	600.0	2.778151	9 33 38
½	5 27 09	63	62.929	21	661.5	2.820530	8 40 12
	5 12 18	66	65.932	22	726.0	2.860937	7 53 54
½	4 58 45	69	68.935	23	793.5	2.899547	7 13 32
	4 46 19	72	71.938	24	864.0	2.936514	6 38 06

Angle and Distance of Middle Frog, *F″*

No. *n″.*	Angle *F″.*	Gauge 4, 8½. Dist. *aF″.*	Gauge 3. Dist. *aF″.*	No. *n.*	No. *n″.*	Angle *F″.*	Gauge 4, 8½. Dist. *aF″.*	Gauge 3. Dist. *aF″.*
2.817	20° 07′ 36″	26.736	17.037	8	5.651	10° 06′ 44″	53.317	33.974
3.172	17 54 52	30.054	19.151	8½	6.005	9 31 08	56.643	36.094
3.527	16 08 19	33.374	21.266	9	6.359	8 59 30	59.969	38.213
3.881	14 40 58	36.695	23.383	9½	6.713	8 31 10	63.296	40.333
4.235	13 27 57	40.018	25.500	10	7.067	8 05 40	66.623	42.453
4.589	12 26 07	43.342	27.618	10½	7.420	7 42 35	69.950	44.573
4.943	*11 33 04*	*46.666*	29.736	11	7.774	7 21 38	73.277	46.693
5.297	*10 47 02*	*49.991*	31.855	11½	8.128	7 02 28	76.605	48.81
5.651	*10 06 44*	*53.317*	33.974	12	8.482	6 44 51	79.932	50.9

TABLE XXIIA.—AMERICAN RAILWAY ENGINEERING ASSOCIATION. SPLIT SWITCH TURNOUTS

PROPERTIES OF FROGS. Thickness of All Frog Points = ½''.							PROPERTIES OF SWITCHES. For All Switches Thickness of Point = 0¼'' and Heel Distance = h = 6¼''.		THEORETICAL LEADS.				
n = Frog Number.	F = Frog Angle.	f = Length Theoretical Point to Toe.	k = Length Theoretical Point to Heel.	Total Length.	Spread at Toe.	Spread at Heel.	l = Length of Switch Rail.	S = Switch Angle.	r = Radius of Center Line.	D = Degree of Lead Curve.	Point of Switch Rail to Theoretical Point of Frog.	Closure Straight Rail	Closure Curved Rail.
4	14° 15' 00''	3' 2''	5' 4''	8' 6''	0.79'	1.32'	11' 0''	2° 36' 19''	112.26'	52° 53' 56''	37.05'	22.88'	23.29'
5	11 25 16	3 7	6 5	10 0	0.71	1.28	11 0	2 36 19	183.22	31 40 24	42.77	28.19	28.55
6	9 31 38	4 0	7 0	11 0	0.66	1.16	11 0	2 36 19	273.95	21 01 58	48.11	33.11	33.38
7	8 10 16	4 5	8 1	12 6	0.63	1.15	16 6	1 44 11	364.88	15 47 19	61.94	41.02	41.24
8	7 09 10	4 9	8 9	13 6	0.59	1.09	16 6	1 44 11	488.71	11 44 40	67.47	46.22	46.42
9	6 21 35	6 0	10 0	16 0	0.67	1.11	16 6	1 44 11	616.27	9 18 27	72.24	49.74	49.92
9½	6 01 32	6 0	10 0	16 0	0.63	1.05	16 6	1 44 11	699.97	8 11 33	74.90	52.40	52.58
10	5 43 29	6 0	10 6	16 6	0.60	1.05	16 6	1 44 11	790.25	7 15 18	77.51	55.01	55.17
11	5 12 18	6 0	11 6	17 6	0.54	1.05	22 0	1 18 8	940.21	6 05 48	92.06	64.06	64.20
12	4 46 19	6 5	12 1	18 6	0.53	1.01	22 0	1 18 8	1136.34	5 02 38	97.25	68.83	68.96
15	3 49 06	7 8	14 10	22 6	0.51	0.99	33 0	0 52 5	1744.45	3 17 06	130.50	89.83	89.94
16	3 34 47	8 0	16 0	24 0	0.50	1.00	33 0	0 52 5	2005.98	2 51 24	135.95	94.95	95.05
18	3 10 56	8 10	17 8	26 6	0.49	0.98	33 0	0 52 5	2587.66	2 12 52	146.38	104.54	104.61
20	2 51 51	9 8	19 4	29 0	0.48	0.97	33 0	0 52 5	3262.98	1 45 22	156.35	113.68	113.76
24	2 23 13	11 4	23 2	34 6	0.47	0.97	33 0	0 52 5	4932.77	1 09 42	175.09	130.66	130.77

TABLE XXIIB.—AMERICAN RAILWAY ENGINEERING ASSOCIATION. SPLIT SWITCH TURNOUTS

PRACTICAL LEADS.

n = Frog Number	r = Radius of Center Line.	D = Degree of Lead Curve.	Tangent Adjacent to Switch Rail.	Tangent Adjacent to Toe of Frog.	Distance Actual Point of Switch Rail to Theoretical Point of Frog.	Distance Actual Point of Switch Rail to Actual Point of Frog.	Closure of Straight Rail.	Closure of Curved Rail.	Rectangular Co-ordinates to the Quarter Center Points on Gauge Side of Curved Rail, Referred to Point of Switch Rail as Origin.					
									X	Y	X_1	Y_1	X_2	Y_2
4	110.69′	53° 42′ 24″	1.03′	0.00′	37.77′	37.94	23.60′	24′	17.74	0.97	23.44	1.67	29.75	2.79
5	174.34	33 19 57	0.00	0.82	42.26	42.47	27.68	28	17.78	0.95	24.54	1.61	31.27	2.62
6	265.39	21 43 04	0.00	0.66	47.73	47.98	32.73	33	19.07	1.01	27.13	1.74	35.15	2.72
7	362.08	15 52 29	0.00	0.19	61.81	62.10	13.89 + 27	14.11 + 27	26.72	0.97	36.93	1.71	47.11	2.74
8	487.48	11 46 27	0.30	0.00	67.65	67.98	16.40 + 30	16.60 + 30	28.37	1.02	39.91	1.78	51.45	2.91
9	605.18	9 28 42	0.00	0.57	71.91	72.28	16.41 + 33	16.59 + 33	28.75	1.02	40.98	1.76	53.19	2.75
9½	695.45	8 14 45	0.76	0.00	75.32	75.71	25.82 + 27	26.00 + 27	30.31	1.06	43.35	1.82	56.37	2.83
10	790.25	7 15 18	0.00	0.00	77.51	77.93	27.00 + 28	27.17 + 28	30.28	1.06	44.05	1.84	57.81	2.85
11	922.65	6 12 47	2.99	0.00	93.85	94.31	32.85 + 33	2 × 33	40.74	1.08	56.47	1.84	72.19	2.87
12	1098.73	5 12 59	5.33	0.00	100.30	100.80	23.88 + 2 × 24	3 × 24	43.99	1.15	60.65	1.90	77.28	2.91
15	1743.80	3 17 10	0.09	0.00	130.56	131.19	29.89 + 2 × 30	3 × 30	55.49	1.01	77.98	1.78	100.45	2.84
16	1993.24	2 52 59	1.56	0.00	136.90	137.57	29.90 + 2 × 33	30.00 + 2 × 33	58.16	1.04	81.76	1.82	105.35	2.87
18	2546.31	2 14 31	0.00	1.08	145.76	146.51	25.93 + 3 × 26	4 × 26	58.73	1.04	84.46	1.82	110.10	2.86
20	3257.26	1 45 32	0.44	0.00	156.59	157.42	26.92 + 2 × 27 + 33	33.00 + 3 × 27	61.84	1.08	90.21	1.88	118.59	2.93
24	4886.16	1 10 21	2.43	0.00	176.22	177.22	32.89 + 3 × 33	4 × 33	67.82	1.27	100.21	1.97	132.59	3.00

TABLE XXI.—MINUTES IN DECIMALS OF A DEGREE

′	0″	10″	15″	20″	30″	40″	45″	50″	′
0	.00000	00278	.00417	.00556	.00833	.01111	.01250	.01389	0
1	.01667	.01944	.02083	.02222	.02500	02778	.02917	.03056	1
2	.03333	.03611	.03750	.03889	.04167	.04444	.04583	.04722	2
3	.05000	.05278	.05417	.05556	.05833	.06111	.06250	.06389	3
4	.06667	.06944	.07083	.07222	.07500	.07778	.07917	.08056	4
5	.08333	.08611	.08750	.08889	.09167	.09444	.09583	.09722	5
6	.10000	.10278	.10417	.10556	.10833	.11111	.11250	.11389	6
7	.11667	.11944	.12083	.12222	.12500	.12778	.12917	.13056	7
8	.13333	.13611	.13750	.13889	.14167	.14444	.14583	.14722	8
9	.15000	.15278	.15417	.15556	.15833	.16111	.16250	.16389	9
10	.16667	.16944	.17083	.17222	.17500	.17778	.17917	.18056	10
11	.18333	.18611	.18750	.18889	.19167	19444	.19583	.19722	11
12	.20000	.20278	.20417	.20556	.20833	.21111	.21250	.21389	12
13	.21667	.21944	.22083	.22222	.22500	.22778	.22917	.23056	13
14	.23333	.23611	.23750	.23889	.24167	.24444	.24583	.24722	14
15	.25000	.25278	.25417	.25556	.25833	.26111	.26250	.26389	15
16	.26667	.26944	.27083	.27222	.27500	.27778	.27917	.28056	16
17	.28333	.28611	.28750	.28889	.29167	.29444	.29583	.29722	17
18	.30000	.30278	.30417	.30556	.30833	.31111	.31250	.31389	18
19	.31667	.31944	.32083	.32222	.32500	.32778	.32917	.33056	19
20	.33333	.33611	.33750	.33889	.34167	.34444	.34583	.34722	20
21	.35000	.35278	.35417	.35556	.35833	.36111	.36250	.36389	21
22	.36667	.36944	.37083	.37222	.37500	.37778	.37917	.38056	22
23	.38333	.38611	.38750	.38889	.39167	.39444	.39583	.39722	23
24	.40000	.40278	.40417	.40556	.40833	.41111	.41250	.41389	24
25	.41667	.41944	.42083	.42222	.42500	.42778	.42917	.43056	25
26	.43333	.43611	.43750	.43889	.44167	.44444	.44583	.44722	26
27	.45000	.45278	.45417	.45556	.45833	.46111	.46250	.46389	27
28	.46667	.46944	.47083	.47222	.47500	.47778	.47917	.48056	28
29	.48333	.48611	.48750	.48889	.49167	.49444	.49583	.49722	29
30	.50000	.50278	.50417	.50556	.50833	.51111	.51250	.51389	30
31	.51667	.51944	.52083	.52222	.52500	.52778	.52917	.53056	31
32	.53333	.53611	.53750	.53889	.54167	.54444	.54583	.54722	32
33	.55000	.55278	.55417	.55556	.55833	.56111	.56250	.56389	33
34	.56667	.56944	.57083	.57222	.57500	.57778	.57917	.58056	34
35	.58333	.58611	.58750	.58889	.59167	.59444	.59583	.59722	35
36	.60000	.60278	.60417	.60556	.60833	.61111	.61250	.61389	36
37	.61667	.61944	.62083	.62222	.62500	.62778	.62917	.63056	37
38	.63333	.63611	.63750	.63889	.64167	.64444	.64583	.64722	38
39	.65000	.65278	.65417	.65556	.65833	.66111	.66250	.66389	39
40	.66667	.66944	.67083	.67222	.67500	.67778	.67917	.68056	40
41	.68333	.68611	.68750	.68889	.69167	.69444	.69583	.69722	41
42	.70000	.70278	.70417	.70556	.70833	.71111	.71250	.71389	42
43	.71667	.71944	.72083	.72222	.72500	.72778	.72917	.73056	43
44	.73333	.73611	.73750	.73889	.74167	.74444	.74583	.74722	44
45	.75000	.75278	.75417	.75556	.75833	.76111	.76250	.76389	45
46	.76667	.76944	.77083	.77222	.77500	.77778	.77917	.78056	46
47	.78333	.78611	.78750	.78889	.79167	.79444	.79583	.79722	47
48	.80000	.80278	.80417	.80556	.80833	.81111	.81250	.81389	48
49	.81667	.81944	.82083	.82222	.82500	.82778	.82917	.83056	49
50	.83333	.83611	.83750	.83889	.84167	.84444	.84583	.84722	50
51	.85000	.85278	.85417	.85556	.85833	86111	.86250	.86389	51
52	.86667	.86944	.87083	.87222	.87500	.87778	.87917	.88056	52
53	.88333	.88611	.88750	.88889	.89167	.89444	.89583	.89722	53
54	.90000	.90278	.90417	.90556	.90833	.91111	.91250	.91389	54
55	.91667	.91944	.92083	.92222	.92500	.92778	.92917	.93056	55
56	.93333	.93611	.93750	.93889	.94167	.94444	.94583	.94722	56
57	.95000	.95278	.95417	.95556	.95833	.96111	.96250	.96389	57
58	.96667	.96944	.97085	.97222	.97500	.97778	.97917	.98056	58
59	.98333	.98611	.98750	.98889	.99167	.99444	.99583	.99722	59
	0″	10″	15″	20″	30″	40″	45″	50″	′

TABLE XXII.—TURNOUTS AND SWITCHES FROM A STRAIGHT TRACK

GAUGE, 4 FEET 8½ INCHES = 4.708. THROW, 5 INCHES = 0.417.

No. *n.*	Angle *F.*	Dist. *BF.*	Chord *af.*	Switch *AD.*	Radius *r.*	Log'thm. *log. r.*	Degree of Curve.
4	14° 15′ 00″	37.664	37.373	11.209	150.656	2.177986	38° 45′ 57″
4½	12 40 49	42.372	42.113	12.610	190.674	2.280292	30 24 09
5	11 25 16	47.080	46.846	14.012	235.400	2.371806	24 31 36
5½	10 23 20	51.788	51.575	15.413	284.834	2.454592	20 13 13
6	9 31 39	56.496	56.301	16.814	338.976	2.530169	16 57 52
6½	8 47 51	61.204	61.024	18.215	397.826	2.599693	14 26 25
7	8 10 16	65.912	65.744	19.616	461.384	2.664063	12 26 34
7½	7 37 41	70.620	70.464	21.017	529.650	2.723989	10 50 02
8	7 09 10	75.328	75.181	22.418	602.624	2.780046	9 31 07
8½	6 43 59	80.036	79.898	23.820	680.306	2.832704	8 25 47
9	6 21 35	84.744	84.613	25.221	762.696	2.882352	7 31 04
9½	6 01 32	89.452	89.328	26.622	849.794	2.929314	6 44 46
10	5 43 29	94.160	94.043	28.023	941.600	2.973866	6 05 16
10½	5 27 09	98.868	98.756	29.424	1038.114	3.016245	5 31 17
11	5 12 18	103.576	103.469	30.825	1139.336	3.056652	5 01 50
11½	4 58 45	108.284	108.182	32.227	1245.266	3.095262	4 36 08
12	4 46 19	112.992	112.894	33.628	1355.904	3.132229	4 13 36

GAUGE, 3 FEET. THROW, 4 INCHES = 0.333.

No. *n.*	Angle *F.*	Dist. *BF.*	Chord *af.*	Switch *AD.*	Radius *r.*	Log'thm. *log. r.*	Degree of Curve.
4	14° 15′ 00″	24	23.815	8	96.0	1.982271	62° 46′ 34″
4½	12 40 49	27	26.835	9	121.5	2.084576	48 36 04
5	11 25 16	30	29.851	10	150.0	2.176091	38 56 33
5½	10 23 20	33	32.865	11	181.5	2.258877	31 58 55
6	9 31 39	36	35.876	12	216.0	2.334454	26 46 07
6½	8 47 51	39	38.885	13	253.5	2.403978	22 45 04
7	8 10 16	42	41.893	14	294.0	2.468347	19 35 01
7½	7 37 41	45	44.900	15	337.5	2.528274	17 02 21
8	7 09 10	48	47.906	16	384.0	2.584331	14 57 48
8½	6 43 59	51	50.912	17	433.5	2.636989	13 14 47
9	6 21 35	54	53.917	18	486.0	2.686636	11 48 37
9½	6 01 32	57	56.921	19	541.5	2.733598	10 35 46
10	5 43 29	60	59.925	20	600.0	2.778151	9 33 38
10½	5 27 09	63	62.929	21	661.5	2.820530	8 40 12
11	5 12 18	66	65.932	22	726.0	2.860937	7 53 54
11½	4 58 45	69	68.935	23	793.5	2.899547	7 13 32
12	4 46 19	72	71.938	24	864.0	2.936514	6 38 06

ANGLE AND DISTANCE OF MIDDLE FROG, *F″*

No. *n.*	No. *n″.*	Angle *F″.*	Gauge 4, 8½. Dist. *aF″.*	Gauge 3. Dist. *aF″.*	No. *n.*	No. *n″.*	Angle *F″.*	Gauge 4, 8½. Dist. *aF″.*	Gauge 3. Dist. *aF″.*
4	2.817	20° 07′ 36″	26.736	17.037	8	5.651	10° 06′ 44″	53.317	33.974
4½	3.172	17 54 52	30.054	19.151	8½	6.005	9 31 08	56.643	36.094
5	3.527	16 08 19	33.374	21.266	9	6.359	8 59 30	59.969	38.213
5½	3.881	14 40 58	36.695	23.383	9½	6.713	8 31 10	63.296	40.333
6	4.235	13 27 57	40.018	25.500	10	7.067	8 05 40	66.623	42.453
6½	4.589	12 26 07	43.342	27.618	10½	7.420	7 42 35	69.950	44.573
7	4.943	11 33 04	46.666	29.736	11	7.774	7 21 38	73.277	46.6
7½	5.297	10 47 03	49.991	31.855	11½	8.128	7 02 28	76.605	48.8
8	5.651	10 06 44	53.317	33.974	12	8.482	6 44 51	79.932	50.

TABLE XXIIA.—AMERICAN RAILWAY ENGINEERING ASSOCIATION. SPLIT SWITCH TURNOUTS

	PROPERTIES OF FROGS. Thickness of All Frog Points = ½″.						PROPERTIES OF SWITCHES. For All Switches Thickness of Point = 0¼″ and Heel Distance = h = 6¼″.		THEORETICAL LEADS.				
n = Frog Number.	F = Frog Angle.	f = Length Theoretical Point to Toe.	k = Length Theoretical Point to Heel.	Total Length.	Spread at Toe.	Spread at Heel.	l = Length of Switch Rail.	S = Switch Angle.	r = Radius of Center Line.	D = Degree of Lead Curve.	Point of Switch Rail to Theoretical Point of Frog.	Closure Straight Rail	Closure Curved Rail.
4	14° 15′ 00″	3′ 2″	5′ 4″	8′ 6″	0.79′	1.32′	11′ 0″	2° 36′ 19″	112.26′	52° 53′ 56″	37.05′	22.88′	23.29′
5	11 25 16	3 7	6 5	10 0	0.71	1.28	11 0	2 36 19	183.22	31 40 24	42.77	28.19	28.55
6	9 31 38	4 0	7 0	11 0	0.66	1.16	11 0	2 36 19	273.95	21 01 58	48.11	33.11	33.38
7	8 10 16	4 5	8 1	12 6	0.63	1.15	16 6	1 44 11	364.88	15 47 19	61.94	41.02	41.24
8	7 09 10	4 9	8 9	13 6	0.59	1.09	16 6	1 44 11	488.71	11 44 40	67.47	46.22	46.42
9	6 21 35	6 0	10 0	16 0	0.67	1.11	16 6	1 44 11	616.27	9 18 27	72.24	49.74	49.92
9½	6 01 32	6 0	10 0	16 0	0.63	1.05	16 6	1 44 11	699.97	8 11 33	74.90	52.40	52.58
10	5 43 29	6 0	10 6	16 6	0.60	1.05	16 6	1 44 11	790.25	7 15 18	77.51	55.01	55.17
11	5 12 18	6 0	11 6	17 6	0.54	1.05	22 0	1 18 8	940.21	6 05 48	92.06	64.06	64.20
12	4 46 19	6 5	12 1	18 6	0.53	1.01	22 0	1 18 8	1136.34	5 02 38	97.25	68.83	68.96
15	3 49 06	7 8	14 10	22 6	0.51	0.99	33 0	0 52 5	1744.45	3 17 06	130.50	89.83	89.94
16	3 34 47	8 0	16 0	24 0	0.50	1.00	33 0	0 52 5	2005.98	2 51 24	135.95	94.95	95.05
18	3 10 56	8 10	17 8	26 6	0.49	0.98	33 0	0 52 5	2587.66	2 12 52	146.38	104.54	104.61
20	2 51 51	9 8	19 4	29 0	0.48	0.97	33 0	0 52 5	3262.98	1 45 22	156.35	113.68	113.76
24	2 23 13	11 4	23 2	34 6	0.47	0.97	33 0	0 52 5	4932.77	1 09 42	175.09	130.66	130.77

TABLE XXIIB.—AMERICAN RAILWAY ENGINEERING ASSOCIATION. SPLIT SWITCH TURNOUTS

n = Frog Number	r = Radius of Center Line.	D = Degree of Lead Curve.	Tangent Adjacent to Switch Rail.	Tangent Adjacent to Toe of Frog.	Distance Actual Point of Switch Rail to Theoretical Point of Frog.	Distance Actual Point of Switch Rail to Actual Point of Frog.	Closure of Straight Rail.	Closure of Curved Rail.	Rectangular Co-ordinates to the Quarter Center Points on Gauge Side of Curved Rail, Referred to Point of Switch Rail as Origin.					
									X	Y	X_1	Y_1	X_2	Y_2
4	110.69′	53° 42′ 24″	1.03′	0.00′	37.77′	37.94	23.60′	24′	17.74	0.97	23.44	1.67	29.75	2.79
5	174.34	33 19 57	0.00	0.82	42.26	42.47	27.68	28	17.78	0.95	24.54	1.61	31.27	2.62
6	265.39	21 43 04	0.00	0.66	47.73	47.98	32.73	33	19.07	1.01	27.13	1.74	35.15	2.72
7	362.08	15 52 29	0.00	0.19	61.81	62.10	13.89 +27	14.11 +27	26.72	0.97	36.93	1.71	47.11	2.74
8	487.48	11 46 27	0.30	0.00	67.65	67.98	16.40 +30	16.60 +30	28.37	1.02	39.91	1.78	51.45	2.91
9	605.18	9 28 42	0.00	0.57	71.91	72.28	16.41 +33	16.59 +33	28.75	1.02	40.98	1.76	53.19	2.75
9½	695.45	8 14 45	0.76	0.00	75.32	75.71	25.82 +27	26.00 +27	30.31	1.06	43.35	1.82	56.37	2.83
10	790.25	7 15 18	0.00	0.00	77.51	77.93	27.00 +28	27.17 +28	30.28	1.06	44.05	1.84	57.81	2.85
11	922.65	6 12 47	2.99	0.00	93.85	94.31	32.85 +33	2 ×33	40.74	1.08	56.47	1.84	72.19	2.87
12	1098.73	5 12 59	5.33	0.00	100.30	100.80	23.88 +2 ×24	3 ×24	43.99	1.15	60.65	1.90	77.28	2.91
15	1743.80	3 17 10	0.09	0.00	130.56	131.19	29.89 +2 ×30	3 ×30	55.49	1.01	77.98	1.78	100.45	2.84
16	1993.24	2 52 59	1.56	0.00	136.90	137.57	29.90 +2 ×33	30.00 +2 ×33	58.16	1.04	81.76	1.82	105.35	2.87
18	2546.31	2 14 31	0.00	1.08	145.76	146.51	25.93 +3 ×26	4 ×26	58.73	1.04	84.46	1.82	110.10	2.86
20	3257.26	1 45 32	0.44	0.00	156.59	157.42	26.92 +2 ×27 +33	33.00 +3 ×27	61.84	1.08	90.21	1.88	118.59	2.93
24	4886.16	1 10 21	2.43	0.00	176.22	177.22	32.89 +3 ×33	4 ×33	67.82	1.27	100.21	1.97	132.59	3.00

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
1	1	1	1.0000000	1.0000000	1.000000000
2	4	8	1.4142136	1.2599210	.500000000
3	9	27	1.7320508	1.4422496	.333333333
4	16	64	2.0000000	1.5874011	.250000000
5	25	125	2.2360680	1.7099759	.200000000
6	36	216	2 4494897	1.8171206	.166666667
7	49	343	2.6457513	1.9129312	.142857143
8	64	512	2.8284271	2.0000000	.125000000
9	81	729	3.0000000	2.0800837	.111111111
10	100	1000	3.1622777	2.1544347	.100000000
11	121	1331	3.3166248	2.2239801	.090909091
12	144	1728	3.4641016	2.2894286	.083333333
13	169	2197	3.6055513	2.3513347	.076923077
14	196	2744	3.7416574	2.4101422	.071428571
15	225	3375	3.8729833	2.4662121	.066666667
16	256	4096	4.0000000	2.5198421	.062500000
17	289	4913	4.1231056	2.5712816	.058823529
18	324	5832	4.2426407	2.6207414	.055555556
19	361	6859	4.3588989	2.6684016	.052631579
20	400	8000	4.4721360	2.7144177	.050000000
21	441	9261	4.5825757	2.7589243	.047619048
22	484	10648	4.6904158	2.8020393	.045454545
23	529	12167	4.7958315	2.8438670	.043478261
24	576	13824	4.8989795	2.8844991	.041666667
25	625	15625	5.0000000	2.9240177	.040000000
26	676	17576	5.0990195	2.9624960	.038461538
27	729	19683	5.1961524	3.0000000	.037037037
28	784	21952	5.2915026	3.0365889	.035714286
29	841	24389	5.3851648	3.0723168	.034482759
30	900	27000	5.4772256	3.1072325	.033333333
31	961	29791	5.5677644	3.1413806	.032258065
32	1024	32768	5.6568542	3.1748021	.031250000
33	1089	35937	5.7445626	3.2075343	030303030
34	1156	39304	5.8309519	3.2396118	.029411765
35	1225	42875	5.9160798	3.2710663	.028571429
36	1296	46656	6.0000000	3.3019272	.027777778
37	1369	50653	6.0827625	3.3322218	.027027027
38	1444	54872	6.1644140	3.3619754	.026315789
39	1521	59319	6.2449980	3.3912114	.025641026
40	1600	64000	6.3245553	3.4199519	.025000000
41	1681	68921	6.4031242	3.4482172	.024390244
42	1764	74088	6.4807407	3.4760266	.023809524
43	1849	79507	6.5574385	3.5033981	.023255814
44	1936	85184	6.6332496	3.5303483	.022727273
45	2025	91125	6.7082039	3.5568933	.022222222
46	2116	97336	6.7823300	3.5830479	.021739130
47	2209	103823	6.8556546	3.6088261	.021276600
48	2304	110592	6.9282032	3.6342411	.020833333
49	2401	117649	7.0000000	3.6593057	.020408163
50	2500	125000	7.0710678	3.6840314	.020000000
51	2601	132651	7.1414284	3.7084298	.019607843
52	2704	140608	7.2111026	3.7325111	.019230769
53	2809	148877	7.2801099	3.7562858	.018867925
54	2916	157464	7.3484692	3.7797631	.018518519
55	3025	166375	7.4161985	3.8029525	.018181818
56	3136	175616	7.4833148	3.8258624	.017857143
57	3249	185193	7.5498344	3.8485011	.017543860
58	3364	195112	7.6157731	3.8708766	.017241379
59	3481	205379	7.6811457	3.8929965	.016949153
60	3600	216000	7.7459667	3.9148676	.016666667
61	3721	226981	7.8102497	3.9364972	.016393443
	3844	238328	7.8740079	3.9578915	.016129032

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
63	3969	250047	7.9372539	3.9790571	.015873016
64	4096	262144	8.0000000	4.0000000	.015625000
65	4225	274625	8.0622577	4.0207256	.015384615
66	4356	287496	8.1240384	4.0412401	.015151515
67	4489	300763	8.1853528	4.0615480	.014925373
68	4624	314432	8.2462113	4.0816551	.014705882
69	4761	328509	8.3066239	4.1015661	.014492754
70	4900	343000	8.3666003	4.1212853	.014285714
71	5041	357911	8 4261498	4.1408178	.014084507
72	5184	373248	8.4852814	4.1601676	.013888889
73	5329	389017	8.5440037	4.1793390	.013698630
74	5476	405224	8.6023253	4.1983364	.013513514
75	5625	421875	8.6602540	4.2171633	.013333333
76	5776	438976	8.7177979	4.2358236	.013157895
77	5929	456533	8.7749644	4.2543210	.012987013
78	6084	474552	8.8317609	4.2726586	.012820513
79	6241	493039	8.8881944	4.2908404	.012658228
80	6400	512000	8.9442719	4.3088695	.012500000
81	6561	531441	9.0000000	4.3267487	.012345679
82	6724	551368	9.0553851	4.3444815	.012195122
83	6889	571787	9.1104336	4.3620707	.012048193
84	7056	592704	9.1651514	4.3795191	.011904762
85	7225	614125	9.2195445	4.3968296	.011764706
86	7396	636056	9.2736185	4.4140049	.011627907
87	7569	658503	9.3273791	4.4310476	.011494253
88	7744	681472	9.3808315	4.4479602	.011363636
89	7921	704969	9.4339811	4.4647451	.011235955
90	8100	729000	9.4868330	4.4814047	.011111111
91	8281	753571	9.5393920	4.4979414	.010989011
92	8464	778688	9.5916630	4.5143574	.010869565
93	8649	804357	9.6436508	4.5306549	.010752688
94	8836	830584	9.6953597	4.5468359	.010638298
95	9025	857375	9.7467943	4.5629026	.010526316
96	9216	884736	9.7979590	4.5788570	.010416667
97	9409	912673	9.8488578	4.5947009	.010309278
98	9604	941192	9.8994949	4.6104363	.010204082
99	9801	970299	9.9498744	4.6260650	.010101010
100	10000	1000000	10.0000000	4.6415888	.010000000
101	10201	1030301	10.0498756	4.6570095	.009900990
102	10404	1061208	10.0995049	4.6723287	.009803922
103	10609	1092727	10.1488916	4.6875482	.009708738
104	10816	1124864	10.1980390	4.7026694	.009615385
105	11025	1157625	10.2469508	4.7176940	.009523810
106	11236	1191016	10.2956301	4.7326235	.009433962
107	11449	1225043	10.3440804	4.7474594	.009345794
108	11664	1259712	10.3923048	4.7622032	.009259259
109	11881	1295029	10.4403065	4.7768562	.009174312
110	12100	1331000	10.4880885	4.7914199	.009090909
111	12321	1367631	10.5356538	4.8058955	.009009009
112	12544	1404928	10.5830052	4.8202845	.008928571
113	12769	1442897	10.6301458	4.8345881	.008849558
114	12996	1481544	10.6770783	4.8488076	.008771930
115	13225	1520875	10.7238053	4.8629442	.008695652
116	13456	1560896	10.7703296	4.8769990	.008620690
117	13689	1601613	10.8166538	4.8909732	.008547009
118	13924	1643032	10.8627805	4.9048681	.008474576
119	14161	1685159	10.9087121	4.9186847	.008403361
120	14400	1728000	10.9544512	4.9324242	.008333333
121	14641	1771561	11.00 0000	4.9460874	.008264463
122	14884	1815848	11.0453610	4.9596757	.008196721
123	15129	1860867	11.0905365	4.9731898	.008130081
124	15376	1906624	11.1355287	4.9866310	.0080645

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
125	15625	1953125	11.1803399	5.0000000	.008000000
126	15876	2000376	11.2249722	5.0132979	.007936508
127	16129	2048383	11.2694277	5.0265257	.007874016
128	16384	2097152	11.3137085	5.0396842	.007812500
129	16641	2146689	11.3578167	5.0527743	.007751938
130	16900	2197000	11.4017543	5.0657970	.007692308
131	17161	2248091	11.4455231	5.0787531	.007633588
132	17424	2299968	11.4891253	5.0916434	.007575758
133	17689	2352637	11.5325626	5.1044687	.007518797
134	17956	2406104	11.5758369	5.1172299	.007462687
135	18225	2460375	11.6189500	5.1299278	.007407407
136	18496	2515456	11.6619038	5.1425632	.007352941
137	18769	2571353	11.7046999	5.1551367	.007299270
138	19044	2628072	11.7473401	5.1676493	.007246377
139	19321	2685619	11.7898261	5.1801015	.007194245
140	19600	2744000	11.8321596	5.1924941	.007142857
141	19881	2803221	11.8743421	5.2048279	.007092199
142	20164	2863288	11.9163753	5.2171034	.007042254
143	20449	2924207	11.9582607	5.2293215	.006993007
144	20736	2985984	12.0000000	5.2414828	.006944444
145	21025	3048625	12.0415946	5.2535879	.006896552
146	21316	3112136	12.0830460	5.2656374	.006849315
147	21609	3176523	12.1243557	5.2776321	.006802721
148	21904	3241792	12.1655251	5.2895725	.006756757
149	22201	3307949	12.2065556	5.3014592	.006711409
150	22500	3375000	12.2474487	5.3132928	.006666667
151	22801	3442951	12.2882057	5.3250740	.006622517
152	23104	3511808	12.3288280	5.3368033	.006578947
153	23409	3581577	12.3693169	5.3484812	.006535948
154	23716	3652264	12.4096736	5.3601084	.006493506
155	24025	3723875	12.4498996	5.3716854	.006451613
156	24336	3796416	12.4899960	5.3832126	.006410256
157	24649	3869893	12.5299641	5 3946907	.006369427
158	24964	3944312	12.5698051	5.4061202	.006329114
159	25281	4019679	12.6095202	5.4175015	.006289308
160	25600	4096000	12.6491106	5.4288352	.006250000
161	25921	4173281	12.6885775	5.4401218	.006211180
162	26244	4251528	12.7279221	5.4513618	.006172840
163	26569	4330747	12.7671453	5.4625556	.006134969
164	26896	4410944	12.8062485	5.4737037	.006097561
165	27225	4492125	12.8452326	5.4848066	.006060606
166	27556	4574296	12.8840987	5.4958647	.006024096
167	27889	4657463	12.9228480	5.5068784	.005988024
168	28224	4741632	12.9614814	5.5178484	.005952381
169	28561	4826809	13.0000000	5.5287748	.005917160
170	28900	4913000	13.0384048	5.5396583	.005882353
171	29241	5000211	13.0766968	5.5504991	.005847953
172	29584	5088448	13.1148770	5.5612978	.005813953
173	29929	5177717	13.1529464	5.5720546	.005780347
174	30276	5268024	13.1909060	5.5827702	.005747126
175	30625	5359375	13.2287566	5.5934447	.005714286
176	30976	5451776	13.2664992	5.6040787	.005681818
177	31329	5545233	13.3041347	5.6146724	.005649718
178	31684	5639752	13.3416641	5.6252263	.005617978
179	32041	5735339	13.3790882	5.6357408	.005586592
180	32400	5832000	13.4164079	5.6462162	.005555556
181	32761	5929741	13.4536240	5.6566528	.005524862
182	33124	6028568	13.4907376	5.6670511	.005494505
183	33489	6128487	13.5277493	5.6774114	.005464481
184	33856	6229504	13.5646600	5.6877340	.005434783
[illegible]	34225	6331625	13.6014705	5.6980192	.005405405
	34596	6434856	13.6381817	5.7082876	.005376344

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
187	34969	6539203	13.6747943	5.7184791	.005347594
188	35344	6644672	13.7113092	5.7286543	.005319149
189	35721	6751269	13.7477271	5.7387936	.005291005
190	36100	6859000	13.7840488	5.7488971	.005263158
191	36481	6967871	13.8202750	5.7589652	.005235602
192	36864	7077888	13.8564065	5.7689982	.005208333
193	37249	7189057	13.8924440	5.7789966	.005181347
194	37636	7301384	13.9283883	5.7889604	.005154639
195	38025	7414875	13.9642400	5.7988900	.005128205
196	38416	7529536	14.0000000	5.8087857	.005102041
197	38809	7645373	14.0356688	5.8186479	.005076142
198	39204	7762392	14.0712473	5.8284767	.005050505
199	39601	7880599	14.1067360	5.8382725	.005025126
200	40000	8000000	14.1421356	5.8480355	.005000000
201	40401	8120601	14.1774469	5.8577660	.004975124
202	40804	8242408	14.2126704	5.8674643	.004950495
203	41209	8365427	14.2478068	5.8771307	.004926108
204	41616	8489664	14.2828569	5.8867653	.004901961
205	42025	8615125	14.3178211	5.8963685	.004878049
206	42436	8741816	14.3527001	5.9059406	.004854369
207	42849	8869743	14.3874946	5.9154817	.004830918
208	43264	8998912	14.4222051	5.9249921	.004807692
209	43681	9129329	14.4568323	5.9344721	.004784689
210	44100	9261000	14.4913767	5.9439220	.004761905
211	44521	9393931	14.5258390	5.9533418	.004739336
212	44944	9528128	14.5602198	5.9627320	.004716981
213	45369	9663597	14.5945195	5.9720926	.004694836
214	45796	9800344	14.6287388	5.9814240	.004672897
215	46225	9938375	14.6628783	5.9907264	.004651163
216	46656	10077696	14.6969385	6.0000000	.004629630
217	47089	10218313	14.7309199	6.0092450	.004608295
218	47524	10360232	14.7648231	6.0184617	.004587156
219	47961	10503459	14.7986486	6.0276502	.004566210
220	48400	10648000	14.8323970	6.0368107	.004545455
221	48841	10793861	14.8660687	6.0459435	.004524887
222	49284	10941048	14.8996644	6.0550489	.004504505
223	49729	11089567	14.9331845	6.0641270	.004484305
224	50176	11239424	14.9666295	6.0731779	.004464286
225	50625	11390625	15.0000000	6.0822020	.004444444
226	51076	11543176	15.0332964	6.0911994	.004424779
227	51529	11697083	15.0665192	6.1001702	.004405286
228	51984	11852352	15.0996689	6.1091147	.004385965
229	52441	12008989	15.1327460	6.1180332	.004366812
230	52900	12167000	15.1657509	6.1269257	.004347826
231	53361	12326391	15.1986842	6.1357924	.004329004
232	53824	12487168	15.2315462	6.1446337	.004310345
233	54289	12649337	15.2643375	6.1534495	.004291845
234	54756	12812904	15.2970585	6.1622401	.004273504
235	55225	12977875	15.3297097	6.1710058	.004255319
236	55696	13144256	15.3622915	6.1797466	.004237288
237	56169	13312053	15.3948043	6.1884628	.004219409
238	56644	13481272	15.4272486	6.1971544	.004201681
239	57121	13651919	15.4596248	6.2058218	.004184100
240	57600	13824000	15.4919334	6.2144650	.004166667
241	58081	13997521	15.5241747	6.2230843	.004149378
242	58564	14172488	15.5563492	6.2316797	.004132231
243	59049	14348907	15.5884573	6.2402515	.004115226
244	59536	14526784	15.6204994	6.2487998	.004098361
245	60025	14706125	15.6524758	6.2573248	.004081633
246	60516	14886936	15.6843871	6.2658266	.004065041
247	61009	15069223	15.7162336	6.2743054	.004048583
248	61504	15252992	15.7480157	6.2827613	.0040[illegible]

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
249	62001	15438249	15.7797338	6.2911946	.004016064
250	62500	15625000	15.8113883	6.2996053	.004000000
251	63001	15813251	15.8429795	6.3079935	.003984064
252	63504	16003008	15.8745079	6.3163596	.003968254
253	64009	16194277	15.9059737	6.3247035	.003952569
254	64516	16387064	15.9373775	6.3330256	.003937008
255	65025	16581375	15.9687194	6.3413257	.003921569
256	65536	16777216	16.0000000	6.3496042	.003906250
257	66049	16974593	16.0312195	6.3578611	.003891051
258	66564	17173512	16.0623784	6.3660968	.003875969
259	67081	17373979	16.0934769	6.3743111	.003861004
260	67600	17576000	16.1245155	6.3825043	.003846154
261	68121	17779581	16.1554944	6.3906765	.003831418
262	68644	17984728	16.1864141	6.3988279	.003816794
263	69169	18191447	16.2172747	6.4069585	.003802281
264	69696	18399744	16.2480768	6.4150687	.003787879
265	70225	18609625	16.2788206	6.4231583	.003773585
266	70756	18821096	16.3095064	6.4312276	.003759398
267	71289	19034163	16.3401346	6.4392767	.003745318
268	71824	19248832	16.3707055	6.4473057	.003731343
269	72361	19465109	16.4012195	6.4553148	.003717472
270	72900	19683000	16.4316767	6.4633041	.003703704
271	73441	19902511	16.4620776	6.4712736	.003690037
272	73984	20123648	16.4924225	6.4792236	.003676471
273	74529	20346417	16.5227116	6.4871541	.003663004
274	75076	20570824	16.5529454	6.4950653	.003649635
275	75625	20796875	16.5831240	6.5029572	.003636364
276	76176	21024576	16.6132477	6.5108300	.003623188
277	76729	21253933	16.6433170	6.5186839	.003610108
278	77284	21484952	16.6733320	6.5265189	.003597122
279	77841	21717639	16.7032931	6.5343351	.003584229
280	78400	21952000	16.7332005	6.5421326	.003571429
281	78961	22188041	16.7630546	6.5499116	.003558719
282	79524	22425768	16.7928556	6.5576722	.003546099
283	80089	22665187	16.8226038	6.5654144	.003533569
284	80656	22906304	16.8522995	6.5731385	.003521127
285	81225	23149125	16.8819430	6.5808443	.003508772
286	81796	23393656	16.9115345	6.5885323	.003496503
287	82369	23639903	16.9410743	6.5962023	.003484321
288	82944	23887872	16.9705627	6.6038545	.003472222
289	83521	24137569	17.0000000	6.6114890	.003460208
290	84100	24389000	17.0293864	6.6191060	.003448276
291	84681	24642171	17.0587221	6.6267054	.003436426
292	85264	24897088	17.0880075	6.6342874	.003424658
293	85849	25153757	17.1172428	6.6418522	.003412969
294	86436	25412184	17.1464282	6.6493998	.003401361
295	87025	25672375	17.1755640	6.6569302	.003389831
296	87616	25934336	17.2046505	6.6644437	.003378378
297	88209	26198073	17.2336879	6.6719403	.003367003
298	88804	26463592	17.2626765	6.6794200	.003355705
299	89401	26730899	17.2916165	6.6868831	.003344482
300	90000	27000000	17.3205081	6.6943295	.003333333
301	90601	27270901	17.3493516	6.7017593	.003322259
302	91204	27543608	17.3781472	6.7091729	.003311258
303	91809	27818127	17.4068952	6.7165700	.003300330
304	92416	28094464	17.4355958	6.7239508	.003289474
305	93025	28372625	17.4642492	6.7313155	.003278689
306	93636	28652616	17.4928557	6.7386641	.003267974
307	94249	28934443	17.5214155	6.7459967	.003257329
308	94864	29218112	17.5499288	6.7533134	.003246753
309	95481	29503629	17.5783958	6.7606143	.003236246
[illegible]	96100	29791000	17.6068169	6.7678995	.003225806

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
311	96721	30080231	17.6351921	6.7751690	.003215434
312	97344	30371328	17.6635217	6.7824229	.003205128
313	97969	30664297	17.6918060	6.7896613	.003194888
314	98596	30959144	17.7200451	6.7968844	.003184713
315	99225	31255875	17.7482393	6.8040921	.003174603
316	99856	31554496	17.7763888	6.8112847	.003164557
317	100489	31855013	17.8044938	6.8184620	.003154574
318	101124	32157432	17.8325545	6.8256242	.003144654
319	101761	32461759	17.8605711	6.8327714	.003134796
320	102400	32768000	17.8885438	6.8399037	.003125000
321	103041	33076161	17.9164729	6.8470213	.003115265
322	103684	33386248	17.9443584	6.8541240	.003105590
323	104329	33698267	17.9722008	6.8612120	.003095975
324	104976	34012224	18.0000000	6.8682855	.003086420
325	105625	34328125	18.0277564	6.8753443	.003076923
326	106276	34645976	18.0554701	6.8823888	.003067485
327	106929	34965783	18.0831413	6.8894188	.003058104
328	107584	35287552	18.1107703	6.8964345	.003048780
329	108241	35611289	18.1383571	6.9034359	.003039514
330	108900	35937000	18.1659021	6.9104232	.003030303
331	109561	36264691	18.1934054	6.9173964	.003021148
332	110224	36594368	18.2208672	6.9243556	.003012048
333	110889	36926037	18.2482876	6.9313008	.003003003
334	111556	37259704	18.2756669	6.9382321	.002994012
335	112225	37595375	18.3030052	6.9451496	.002985075
336	112896	37933056	18.3303028	6.9520533	.002976190
337	113569	38272753	18.3575598	6.9589434	.002967359
338	114244	38614472	18.3847763	6.9658198	.002958580
339	114921	38958219	18.4119526	6.9726826	.002949853
340	115600	39304000	18.4390889	6.9795321	.002941176
341	116281	39651821	18.4661853	6.9863681	.002932551
342	116964	40001688	18.4932420	6.9931906	.002923977
343	117649	40353607	18.5202592	7.0000000	.002915452
344	118336	40707584	18.5472370	7.0067962	.002906977
345	119025	41063625	18.5741756	7 0135791	.002898551
346	119716	41421736	18.6010752	7.0203490	.002890173
347	120409	41781923	18.6279360	7.0271058	.002881844
348	121104	42144192	18.6547581	7.0338497	.002873563
349	121801	42508549	18.6815417	7.0405806	.002865330
350	122500	42875000	18.7082869	7.0472987	.002857143
351	123201	43243551	18.7349940	7.0540041	.002849003
352	123904	43614208	18.7616630	7.0606967	.002840909
353	124609	43986977	18.7882942	7.0673767	.002832861
354	125316	44361864	18.8148877	7.0740440	.002824859
355	126025	44738875	18.8414437	7.0806988	.002816901
356	126736	45118016	18.8679623	7.0873411	.002808989
357	127449	45499293	18.8944436	7.0939709	.002801120
358	128164	45882712	18.9208879	7.1005885	.002793296
359	128881	46268279	18.9472953	7.1071937	.002785515
360	129600	46656000	18.9736660	7.1137866	.002777778
361	130321	47045881	19.0000000	7.1203674	.002770083
362	131044	47437928	19.0262976	7.1269360	.002762431
363	131769	47832147	19.0525589	7.1334925	.002754821
364	132496	48228544	19.0787840	7.1400370	.002747253
365	133225	48627125	19.1049732	7.1465695	.002739726
366	133956	49027896	19.1311265	7.1530901	.002732240
367	134689	49430863	19.1572441	7.1595988	.002724796
368	135424	49836032	19.1833261	7.1660957	.002717391
369	136161	50243409	19.2093727	7.1725809	.002710027
370	136900	50653000	19.2353841	7.1790544	.002702703
371	137641	51064811	19.2613603	7.1855162	.002695418
372	138384	51478848	19.2873015	7.1919663	.002688172

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
373	139129	51895117	19.3132079	7.1984050	.002680965
374	139876	52313624	19.3390796	7.2048322	.002673797
375	140625	52734375	19.3649167	7.2112479	.002666667
376	141376	53157376	19.3907194	7.2176522	.002659574
377	142129	53582633	19.4164878	7.2240450	.002652520
378	142884	54010152	19.4422221	7.2304268	.002645503
379	143641	54439939	19.4679223	7.2367972	.002638522
380	144400	54872000	19.4935887	7.2431565	.002631579
381	145161	55306341	19.5192213	7.2495045	.002624672
382	145924	55742968	19.5448203	7.2558415	.002617801
383	146689	56181887	19.5703858	7.2621675	.002610966
384	147456	56623104	19.5959179	7.2684824	.002604167
385	148225	57066625	19.6214169	7.2747864	.002597403
386	148996	57512456	19.6468827	7.2810794	.002590674
387	149769	57960603	19.6723156	7.2873617	.002583979
388	150544	58411072	19.6977156	7.2936330	.002577320
389	151321	58863869	19.7230829	7.2998936	.002570694
390	152100	59319000	19.7484177	7.3061436	.002564103
391	152881	59776471	19.7737199	7.3123828	.002557545
392	153664	60236288	19.7989899	7.3186114	.002551020
393	154449	60698457	19.8242276	7.3248295	.002544529
394	155236	61162984	19.8494332	7.3310369	.002538071
395	156025	61629875	19.8746069	7.3372339	.002531646
396	156816	62099136	19.8997487	7.3434205	.002525253
397	157609	62570773	19.9248588	7.3495966	.002518892
398	158404	63044792	19.9499373	7.3557624	.002512563
399	159201	63521199	19.9749844	7.3619178	.002506266
400	160000	64000000	20.0000000	7.3680630	.002500000
401	160801	64481201	20.0249844	7.3741979	.002493766
402	161604	64964808	20.0499377	7.3803227	.002487562
403	162409	65450827	20.0748599	7.3864373	.002481390
404	163216	65939264	20.0997512	7.3925418	.002475248
405	164025	66430125	20.1246118	7.3986363	.002469136
406	164836	66923416	20.1494417	7.4047206	.002463054
407	165649	67419143	20.1742410	7.4107950	.002457002
408	166464	67917312	20.1990099	7.4168595	.002450980
409	167281	68417929	20.2237484	7.4229142	.002444988
410	168100	68921000	20.2484567	7.4289589	.002439024
411	168921	69426531	20.2731349	7.4349938	.002433090
412	169744	69934528	20.2977831	7.4410189	.002427184
413	170569	70444997	20.3224014	7.4470342	.002421308
414	171396	70957944	20.3469899	7.4530899	.002415459
415	172225	71473375	20.3715488	7.4590859	.002409639
416	173056	71991296	20.3960781	7.4650223	.002403846
417	173889	72511713	20.4205779	7.4709991	.002398082
418	174724	73034632	20.4450483	7.4769664	.002392344
419	175561	73560059	20.4694895	7.4829242	.002386635
420	176400	74088000	20.4939015	7.4888724	.002380952
421	177241	74618461	20.5182845	7.4948113	.002375297
422	178084	75151448	20.5426386	7.5007406	.002369668
423	178929	75686967	20.5669638	7.5066607	.002364066
424	179776	76225024	20 5912603	7.5125715	.002358491
425	180625	76765625	20.6155281	7.5184730	.002352941
426	181476	77308776	20.6397674	7.5243652	.002347418
427	182329	77854483	20.6639783	7.5302482	.002341920
428	183184	78402752	20.6881609	7.5361221	.002336449
429	184041	78953589	20.7123152	7.5419867	.002331002
430	184900	79507000	20.7364414	7.5478423	.002325581
431	185761	80062991	20.7605395	7.5536888	.002320186
[illegible]	*186624*	80621568	20.7846097	7.5595263	.002314815
[illegible]	*187489*	81182737	20.8086520	7.5653548	.002309469
[illegible]	*188356*	81746504	20.8326667	7.5711743	.002304147

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
559	312481	174676879	23.6431808	8.2376614	.001788909
560	313600	175616000	23.6643191	8.2425706	.001785714
561	314721	176558481	23.6854386	8.2474740	.001782531
562	315844	177504328	23.7065392	8.2523715	.001779359
563	316969	178453547	23.7276210	8.2572633	.001776199
564	318096	179406144	23.7486842	8.2621492	.001773050
565	319225	180362125	23.7697286	8.2670294	.001769912
566	320356	181321496	23.7907545	8.2719039	.001766784
567	321489	182284263	23.8117618	8.2767726	.001763668
568	322624	183250432	23.8327506	8.2816355	.001760563
569	323761	184220009	23.8537209	8.2864928	.001757469
570	324900	185193000	23.8746728	8.2913444	.001754386
571	326041	186169411	23.8956063	8.2961903	.001751313
572	327184	187149248	23.9165215	8.3010304	.001748252
573	328329	188132517	23.9374184	8.3058651	.001745201
574	329476	189119224	23.9582971	8.3106941	.001742160
575	330625	190109375	23.9791576	8.3155175	.001739130
576	331776	191102976	24.0000000	8.3203353	.001736111
577	332929	192100033	24.0208243	8.3251475	.001733102
578	334084	193100552	24.0416306	8.3299542	.001730104
579	335241	194104529	24.0624188	8.3347553	.001727116
580	336400	195112000	24.0831891	8.3395509	.001724138
581	337561	196122941	24.1039416	8.3443410	.001721170
582	338724	197137368	24.1246762	8.3491256	.001718213
583	339889	198155287	24.1453929	8.3539047	.001715266
584	341056	199176704	24.1660919	8.3586784	.001712329
585	342225	200201625	24.1867732	8.3634466	.001709402
586	343396	201230056	24.2074369	8.3682095	.001706485
587	344569	202262003	24.2280829	8.3729668	.001703578
588	345744	203297472	24.2487113	8.3777188	.001700680
589	346921	204336469	24.2693222	8.3824653	.001697793
590	348100	205379000	24.2899156	8.3872065	.001694915
591	349281	206425071	24.3104916	8.3919423	.001692047
592	350464	207474688	24.3310501	8.3966729	.001689189
593	351649	208527857	24.3515913	8.4013981	.001686341
594	352836	209584584	24.3721152	8.4061180	.001683502
595	354025	210644875	24.3926218	8.4108326	.001680672
596	355216	211708736	24.4131112	8.4155419	.001677852
597	356409	212776173	24.4335834	8.4202460	.001675042
598	357604	213847192	24.4540385	8.4249448	.001672241
599	358801	214921799	24.4744765	8.4296383	.001669449
600	360000	216000000	24.4948974	8.4343267	.001666667
601	361201	217081801	24.5153013	8.4390098	.001663894
602	362404	218167208	24.5356883	8.4436877	.001661130
603	363609	219256227	24.5560583	8.4483605	.001658375
604	364816	220348864	24.5764115	8.4530281	.001655629
605	366025	221445125	24.5967478	8.4576906	.001652893
606	367236	222545016	24.6170673	8.4623479	.001650165
607	368449	223648543	24.6373700	8.4670001	.001647446
608	369664	224755712	24.6576560	8.4716471	.001644737
609	370881	225866529	24.6779254	8.4762892	.001642036
610	372100	226981000	24.6981781	8.4809261	.001639344
611	373321	228099131	24.7184142	8.4855579	.001636661
612	374544	229220928	24.7386338	8.4901848	.001633987
613	375769	230346397	24.7588368	8.4948065	.001631321
614	376996	231475544	24.7790234	8.4994233	.001628664
615	378225	232608375	24.7991935	8.5040350	.001626016
616	379456	233744896	24.8193473	8.5086417	.001623377
617	380689	234885113	24.8394847	8.5132435	.001620746
618	381924	236029032	24.8596058	8.5178403	.001618123
619	383161	237176659	24.8797106	8.5224321	.001615509
620	384400	238328000	24.8997992	8.5270189	.001612903

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
497	247009	122763473	22.2934968	7.9210994	.002012072
498	248004	123505992	22.3159136	7.9264085	.002008032
499	249001	124251499	22.3383079	7.9317104	.002004008
500	250000	125000000	22.3606798	7.9370053	.002000000
501	251001	125751501	22.3830293	7.9422931	.001996008
502	252004	126506008	22.4053565	7.9475739	.001992032
503	253009	127263527	22.4276615	7.9528477	.001988072
504	254016	128024064	22.4499443	7.9581144	.001984127
505	255025	128787625	22.4722051	7.9633743	.001980198
506	256036	129554216	22.4944438	7.9686271	.001976285
507	257049	130323843	22.5166605	7.9738731	.001972387
508	258064	131096512	22.5388553	7.9791122	.001968504
509	259081	131872229	22.5610283	7.9843444	.001964637
510	260100	132651000	22.5831796	7.9895697	.001960784
511	261121	133432831	22.6053091	7.9947883	.001956947
512	262144	134217728	22.6274170	8.0000000	.001953125
513	263169	135005697	22.6495033	8.0052049	.001949318
514	264196	135796744	22.6715681	8.0104032	.001945525
515	265225	136590875	22.6936114	8.0155946	.001941748
516	266256	137388096	22.7156334	8.0207794	.001937984
517	267289	138188413	22.7376340	8.0259574	.001934236
518	268324	138991832	22.7596134	8.0311287	.001930502
519	269361	139798359	22.7815715	8.0362935	.001926782
520	270400	140608000	22.8035085	8.0414515	.001923077
521	271441	141420761	22.8254244	8.0466030	.001919386
522	272484	142236648	22.8473193	8.0517479	.001915709
523	273529	143055667	22.8691933	8.0568862	.001912046
524	274576	143877824	22.8910463	8.0620180	.001908397
525	275625	144703125	22.9128785	8.0671432	.001904762
526	276676	145531576	22.9346899	8.0722620	.001901141
527	277729	146363183	22.9564806	8.0773743	.001897533
528	278784	147197952	22.9782506	8.0824800	.001893939
529	279841	148035889	23.0000000	8.0875794	.001890359
530	280900	148877000	23.0217289	8.0926723	.001886792
531	281961	149721291	23.0434372	8.0977589	.001883239
532	283024	150568768	23.0651252	8.1028390	.001879699
533	284089	151419437	23.0867928	8.1079128	.001876173
534	285156	152273304	23.1084400	8.1129803	.001872659
535	286225	153130375	23.1300670	8.1180414	.001869159
536	287296	153990656	23.1516738	8.1230962	.001865672
537	288369	154854153	23.1732605	8.1281447	.001862197
538	289444	155720872	23.1948270	8.1331870	.001858736
539	290521	156590819	23.2163735	8.1382230	.001855288
540	291600	157464000	23.2379001	8.1432529	.001851852
541	292681	158340421	23.2594067	8.1482765	.001848429
542	293764	159220088	23.2808935	8.1532939	.001845018
543	294849	160103007	23.3023604	8.1583051	.001841621
544	295936	160989184	23 3238076	8.1633102	.001838235
545	297025	161878625	23.3452351	8.1683092	.001834862
546	298116	162771336	23.3666429	8.1733020	.001831502
547	299209	163667323	23.3880311	8.1782888	.001828154
548	300304	164566592	23.4093998	8.1832695	.001824818
549	301401	165469149	23.4307490	8.1882441	.001821494
550	302500	166375000	23.4520788	8.1932127	.001818182
551	303601	167284151	23.4733892	8.1981753	.001814882
552	304704	168196608	23.4946802	8.2031319	.001811594
553	305809	169112377	23.5159520	8.2080825	.001808318
554	306916	170031464	23.5372046	8.2130271	.001805054
555	308025	170953875	23.5584380	8.2179657	.001801802
[illegible]	309136	171879616	23.5796522	8.2228985	.001798561
[illegible]	310249	172808693	23.6008474	8.2278254	.001795332
[illegible]	311364	173741112	23.6220236	8.2327463	.001792115

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
559	312481	174676879	23.6431808	8.2376614	.001788909
560	313600	175616000	23.6643191	8.2425706	.001785714
561	314721	176558481	23.6854386	8.2474740	.001782531
562	315844	177504328	23.7065392	8.2523715	.001779359
563	316969	178453547	23.7276210	8.2572633	.001776199
564	318096	179406144	23.7486842	8.2621492	.001773050
565	319225	180362125	23.7697286	8.2670294	.001769912
566	320356	181321496	23.7907545	8.2719039	.001766784
567	321489	182284263	23.8117618	8.2767726	.001763668
568	322624	183250432	23.8327506	8.2816355	.001760563
569	323761	184220009	23.8537209	8.2864928	.001757469
570	324900	185193000	23.8746728	8.2913444	.001754386
571	326041	186169411	23.8956063	8.2961903	.001751313
572	327184	187149248	23.9165215	8.3010304	.001748252
573	328329	188132517	23.9374184	8.3058651	.001745201
574	329476	189119224	23.9582971	8.3106941	.001742160
575	330625	190109375	23.9791576	8.3155175	.001739130
576	331776	191102976	24.0000000	8.3203353	.001736111
577	332929	192100033	24.0208243	8.3251475	.001733102
578	334084	193100552	24.0416306	8.3299542	.001730104
579	335241	194104539	24.0624188	8.3347553	.001727116
580	336400	195112000	24.0831891	8.3395509	.001724138
581	337561	196122941	24.1039416	8.3443410	.001721170
582	338724	197137368	24.1246762	8.3491256	.001718213
583	339889	198155287	24.1453929	8.3539047	.001715266
584	341056	199176704	24.1660919	8.3586784	.001712329
585	342225	200201625	24.1867732	8.3634466	.001709402
586	343396	201230056	24.2074369	8.3682095	.001706485
587	344569	202262003	24.2280829	8.3729668	.001703578
588	345744	203297472	24.2487113	8.3777188	.001700680
589	346921	204336469	24.2693222	8.3824653	.001697793
590	348100	205379000	24.2899156	8.3872065	.001694915
591	349281	206425071	24.3104916	8.3919423	.001692047
592	350464	207474688	24.3310501	8.3966729	.001689189
593	351649	208527857	24.3515913	8.4013981	.001686341
594	352836	209584584	24.3721152	8.4061180	.001683502
595	354025	210644875	24.3926218	8.4108326	.001680672
596	355216	211708736	24.4131112	8.4155419	.001677852
597	356409	212776173	24.4335834	8.4202460	.001675042
598	357604	213847192	24.4540385	8.4249448	.001672241
599	358801	214921799	24.4744765	8.4296383	.001669449
600	360000	216000000	24.4948974	8.4343267	.001666667
601	361201	217081801	24.5153013	8.4390098	.001663894
602	362404	218167208	24.5356883	8.4436877	.001661130
603	363609	219256227	24.5560583	8.4483605	.001658375
604	364816	220348864	24.5764115	8.4530281	.001655629
605	366025	221445125	24.5967478	8.4576906	.001652893
606	367236	222545016	24.6170673	8.4623479	.001650165
607	368449	223648543	24.6373700	8.4670001	.001647446
608	369664	224755712	24.6576560	8.4716471	.001644737
609	370881	225866529	24.6779254	8.4762892	.001642036
610	372100	226981000	24.6981781	8.4809261	.001639344
611	373321	228099131	24.7184142	8.4855579	.001636661
612	374544	229220928	24.7386338	8.4901848	.001633987
613	375769	230346397	24.7588368	8.4948065	.001631321
614	376996	231475544	24.7790234	8.4994233	.001628664
615	378225	232608375	24.7991935	8.5040350	.001626016
616	379456	233744896	24.8193473	8.5086417	.001623377
617	380689	234885113	24.8394847	8.5132435	.001620746
618	381924	236029032	24.8596058	8.5178403	.001618123
619	383161	237176659	24.8797106	8.5224321	.001615509
620	384400	238328000	24.8997992	8.5270189	.001612903

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
621	385641	239483061	24.9198716	8.5316009	.001610306
622	386884	240641848	24.9399278	8.5361780	.001607717
623	388129	241804367	24.9599679	8.5407501	.001605136
624	389376	242970624	24.9799920	8.5453173	.001602564
625	390625	244140625	25.0000000	8.5498797	.001600000
626	391876	245314376	25.0199920	8.5544372	.001597444
627	393129	246491883	25.0399681	8.5589899	.001594896
628	394384	247673152	25.0599282	8.5635377	.001592357
629	395641	248858189	25.0798724	8.5680807	.001589825
630	396900	250047000	25.0998008	8.5726189	.001587302
631	398161	251239591	25.1197134	8.5771523	.001584786
632	399424	252435968	25.1396102	8.5816809	.001582278
633	400689	253636137	25.1594913	8.5862047	.001579779
634	401956	254840104	25.1793566	8.5907238	.001577287
635	403225	256047875	25.1992063	8.5952380	.001574803
636	404496	257259456	25.2190404	8.5997476	.001572327
637	405769	258474853	25.2388589	8.6042525	.001569859
638	407044	259694072	25.2586619	8.6087526	.001567398
639	408321	260917119	25.2784493	8.6132480	.001564945
640	409600	262144000	25.2982213	8.6177388	.001562500
641	410881	263374721	25.3179778	8.6222248	.001560062
642	412164	264609288	25.3377189	8.6267063	.001557632
643	413449	265847707	25.3574447	8.6311830	.001555210
644	414736	267089984	25.3771551	8.6356551	.001552795
645	416025	268336125	25.3968502	8.6401226	.001550388
646	417316	269586136	25.4165301	8.6445855	.001547988
647	418609	270840023	25.4361947	8.6490437	.001545595
648	419904	272097792	25.4558441	8.6534974	.001543210
649	421201	273359449	25.4754784	8.6579465	.001540832
650	422500	274625000	25.4950976	8.6623911	.001538462
651	423801	275894451	25.5147016	8.6668310	.001536098
652	425104	277167808	25.5342907	8.6712665	.001533742
653	426409	278445077	25.5538647	8.6756974	.001531394
654	427716	279726264	25.5734237	8.6801237	.001529052
655	429025	281011375	25.5929678	8.6845456	.001526718
656	430336	282300416	25.6124969	8.6889630	.001524390
657	431649	283593393	25.6320112	8.6933759	.001522070
658	432964	284890312	25.6515107	8.6977843	.001519757
659	434281	286191179	25.6709953	8.7021882	.001517451
660	435600	287496000	25.6904652	8.7065877	.001515152
661	436921	288804781	25.7099203	8.7109827	.001512859
662	438244	290117528	25.7293607	8.7153734	.001510574
663	439569	291434247	25.7487864	8.7197596	.001508296
664	440896	292754944	25.7681975	8.7241414	.001506024
665	442225	294079625	25.7875939	8.7285187	.001503759
666	443556	295408296	25.8069758	8.7328918	.001501502
667	444889	296740963	25.8263431	8.7372604	.001499250
668	446224	298077632	25.8456960	8.7416246	.001497006
669	447561	299418309	25.8650343	8.7459846	.001494768
670	448900	300763000	25.8843582	8.7503401	.001492537
671	450241	302111711	25.9036677	8.7546913	.001490313
672	451584	303464448	25.9229628	8.7590383	.001488095
673	452929	304821217	25.9422435	8.7633809	.001485884
674	454276	306182024	25.9615100	8.7677192	.001483680
675	455625	307546875	25.9807621	8.7720532	.001481481
676	456976	308915776	26.0000000	8.7763830	.001479290
677	458329	310288733	26.0192237	8.7807084	.001477105
678	459684	311665752	26.0384331	8.7850296	.001474926
679	461041	313046839	26.0576284	8.7893466	.001472754
[illegible]	462400	314432000	26.0768096	8.7936593	.001470588
	463761	315821241	26.0959767	8.7979679	.001468429
	465124	317214568	26.1151297	8.8022721	.001466276

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
683	466489	318611987	26.1342687	8.8065722	.001464129
684	467856	320013504	26.1533937	8.8108681	.001461988
685	469225	321419125	26.1725047	8.8151598	.001459854
686	470596	322828856	26.1916017	8.8194474	.001457726
687	471969	324242703	26.2106848	8.8237307	.001455604
688	473344	325660672	26.2297541	8.8280099	.001453488
689	474721	327082769	26.2488095	8.8322850	.001451379
690	476100	328509000	26.2678511	8.8365559	.001449275
691	477481	329939371	26.2868789	8.8408227	.001447178
692	478864	331373888	26.3058929	8.8450854	.001445087
693	480249	332812557	26.3248932	8.8493440	.001443001
694	481636	334255384	26.3438797	8.8535985	.001440922
695	483025	335702375	26.3628527	8.8578489	.001438849
696	484416	337153536	26.3818119	8.8620952	.001436782
697	485809	338608873	26.4007576	8.8663375	.001434720
698	487204	340068392	26.4196896	8.8705757	.001432665
699	488601	341532099	26.4386081	8.8748099	.001430615
700	490000	343000000	26.4575131	8.8790400	.001428571
701	491401	344472101	26.4764046	8.8832661	.001426534
702	492804	345948408	26.4952826	8.8874882	.001424501
703	494209	347428927	26.5141472	8.8917063	.001422475
704	495616	348913664	26.5329983	8.8959204	.001420455
705	497025	350402625	26.5518361	8.9001304	.001418440
706	498436	351895816	26.5706605	8.9043366	.001416431
707	499849	353393243	26.5894716	8.9085387	.001414427
708	501264	354894912	26.6082694	8.9127369	.001412429
709	502681	356400829	26.6270539	8.9169311	.001410437
710	504100	357911000	26.6458252	8.9211214	.001408451
711	505521	359425431	26.6645833	8.9253078	.001406470
712	506944	360944128	26.6833281	8.9294902	.001404494
713	508369	362467097	26.7020598	8.9336687	.001402525
714	509796	363994344	26.7207784	8.9378433	.001400560
715	511225	365525875	26.7394839	8.9420140	.001398601
716	512656	367061696	26.7581763	8.9461809	.001396648
717	514089	368601813	26.7768557	8.9503438	.001394700
718	515524	370146232	26.7955220	8.9545029	.001392758
719	516961	371694959	26.8141754	8.9586581	.001390821
720	518400	373248000	26.8328157	8.9628095	.001388889
721	519841	374805361	26.8514432	8.9669570	.001386963
722	521284	376367048	26.8700577	8.9711007	.001385042
723	522729	377933067	26.8886593	8.9752406	.001383126
724	524176	379503424	26.9072481	8.9793766	.001381215
725	525625	381078125	26.9258240	8.9835089	.001379310
726	527076	382657176	26.9443872	8.9876373	.001377410
727	528529	384240583	26.9629375	8.9917620	.001375516
728	529984	385828352	26.9814751	8.9958829	.001373626
729	531441	387420489	27.0000000	9.0000000	.001371742
730	532900	389017000	27.0185122	9.0041134	.001369863
731	534361	390617891	27.0370117	9.0082229	.001367989
732	535824	392223168	27.0554985	9.0123288	.001366120
733	537289	393832837	27.0739727	9.0164309	.001364256
734	538756	395446904	27.0924344	9.0205293	.001362398
735	540225	397065375	27.1108834	9.0246239	.001360544
736	541696	398688256	27.1293199	9.0287149	.001358696
737	543169	400315553	27.1477439	9.0328021	.001356852
738	544644	401947272	27.1661554	9.0368857	.001355014
739	546121	403583419	27.1845544	9.0409655	.001353180
740	547600	405224000	27.2029410	9.0450417	.001351351
741	549081	406869021	27.2213152	9.0491142	.001349528
742	550564	408518488	27.2396769	9.0531831	.001347709
743	552049	410172407	27.2580263	9.0572482	.0013458
744	553536	411830784	27.2763634	9.0613098	.0013

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
745	555025	413493625	27.2946881	9.0653677	.001342282
746	556516	415160936	27.3130006	9.0694220	.001340483
747	558009	416832723	27.3313007	9.0734726	.001338688
748	559504	418508992	27.3495887	9.0775197	.001336898
749	561001	420189749	27.3678644	9.0815631	.001335113
750	562500	421875000	27.3861279	9.0856030	.001333333
751	564001	423564751	27.4043792	9.0896392	.001331558
752	565504	425259008	27.4226184	9.0936719	.001329787
753	567009	426957777	27.4408455	9.0977010	.001328021
754	568516	428661064	27.4590604	9.1017265	.001326260
755	570025	430368875	27.4772633	9.1057485	.001324503
756	571536	432081216	27.4954542	9.1097669	.001322751
757	573049	433798093	27.5136330	9.1137818	.001321004
758	574564	435519512	27.5317998	9.1177931	.001319261
759	576081	437245479	27.5499546	9.1218010	.001317523
760	577600	438976000	27.5680975	9.1258053	.001315789
761	579121	440711081	27.5862284	9.1298061	.001314060
762	580644	442450728	27.6043475	9.1338034	.001312336
763	582169	444194947	27.6224546	9.1377971	.001310616
764	583696	445943744	27.6405499	9.1417874	.001308901
765	585225	447697125	27.6586334	9.1457742	.001307190
766	586756	449455096	27.6767050	9.1497576	.001305483
767	588289	451217663	27.6947648	9.1537375	.001303781
768	589824	452984832	27.7128129	9.1577139	.001302083
769	591361	454756609	27.7308492	9.1616869	.001300390
770	592900	456533000	27.7488739	9.1656565	.001298701
771	594441	458314011	27.7668868	9.1696225	.001297017
772	595984	460099648	27.7848880	9.1735852	.001295337
773	597529	461889917	27.8028775	9.1775445	.001293661
774	599076	463684824	27.8208555	9.1815003	.001291990
775	600625	465484375	27.8388218	9.1854527	.001290323
776	602176	467288576	27.8567766	9.1894018	.001288660
777	603729	469097433	27.8747197	9.1933474	.001287001
778	605284	470910952	27.8926514	9.1972897	.001285347
779	606841	472729139	27.9105715	9.2012286	.001283697
780	608400	474552000	27.9284801	9.2051641	.001282051
781	609961	476379541	27.9463772	9.2090962	.001280410
782	611524	478211768	27.9642629	9.2130250	.001278772
783	613089	480048687	27.9821372	9.2169505	.001277139
784	614656	481890304	28.0000000	9.2208726	.001275510
785	616225	483736625	28.0178515	9.2247914	.001273885
786	617796	485587656	28.0356915	9.2287068	.001272265
787	619369	487443403	28.0535203	9.2326189	.001270648
788	620944	489303872	28.0713377	9.2365277	.001269036
789	622521	491169069	28.0891438	9.2404333	.001267427
790	624100	493039000	28.1069386	9.2443355	.001265823
791	625681	494913671	28.1247222	9.2482344	.001264223
792	627264	496793088	28.1424946	9.2521300	.001262626
793	628849	498677257	28.1602557	9.2560224	.001261034
794	630436	500566184	28.1780056	9.2599114	.001259446
795	632025	502459875	28.1957444	9.2637973	.001257862
796	633616	504358336	28.2134720	9.2676798	.001256281
797	635209	506261573	28.2311884	9.2715592	.001254705
798	636804	508169592	28.2488938	9.2754352	.001253133
799	638401	510082399	28.2665881	9.2793081	.001251564
800	640000	512000000	28.2842712	9.2831777	.001250000
801	641601	513922401	28.3019434	9.2870440	.001248439
802	643204	515849608	28.3196045	9.2909072	.001246883
803	644809	517781627	28.3372546	9.2947671	.001245330
[illegible]	646416	519718464	28.3548938	9.2986239	.001243781
	648025	521660125	28.3725219	9.3024775	.001242236
	649636	523606616	28.3901391	9.3063278	.001240695

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
807	651249	525557943	28.4077454	9.3101750	.001239157
808	652864	527514112	28.4253408	9.3140190	.001237624
809	654481	529475129	28.4429253	9.3178599	.001236094
810	656100	531441000	28.4604989	9.3216975	.001234568
811	657721	533411731	28.4780617	9.3255320	.001233046
812	659344	535387328	28.4956137	9.3293634	.001231527
813	660969	537367797	28.5131549	9.3331916	.001230012
814	662596	539353144	28.5306852	9.3370167	.001228501
815	664225	541343375	28.5482048	9.3408386	.001226994
816	665856	543338496	28.5657137	9.3446575	.001225490
817	667489	545338513	28.5832119	9.3484731	.001223990
818	669124	547343432	28.6006993	9.3522857	.001222494
819	670761	549353259	28.6181760	9.3560952	.001221001
820	672400	551368000	28.6356421	9.3599016	.001219512
821	674041	553387661	28.6530976	9.3637049	.001218027
822	675684	555412248	28.6705424	9.3675051	.001216545
823	677329	557441767	28.6879766	9.3713022	.001215067
824	678976	559476224	28.7054002	9.3750963	.001213592
825	680625	561515625	28.7228132	9.3788873	.001212121
826	682276	563559976	28.7402157	9.3826752	.001210654
827	683929	565609283	28.7576077	9.3864600	.001209190
828	685584	567663552	28.7749891	9.3902419	.001207729
829	687241	569722789	28.7923601	9.3940206	.001206273
830	688900	571787000	28.8097206	9.3977964	.001204819
831	690561	573856191	28.8270706	9.4015691	.001203369
832	692224	575930368	28.8444102	9.4053387	.001201923
833	693889	578009537	28.8617394	9.4091054	.001200480
834	695556	580093704	28.8790582	9.4128690	.001199041
835	697225	582182875	28.8963666	9.4166297	.001197605
836	698896	584277056	28.9136646	9.4203873	.001196172
837	700569	586376253	28.9309523	9.4241420	.001194743
838	702244	588480472	28.9482297	9.4278936	.001193317
839	703921	590589719	28.9654967	9.4316423	.001191895
840	705600	592704000	28.9827535	9.4353880	.001190476
841	707281	594823321	29.0000000	9.4391307	.001189061
842	708964	596947688	29.0172363	9.4428704	.001187648
843	710649	599077107	29.0344623	9.4466072	.001186240
844	712336	601211584	29.0516781	9.4503410	.001184834
845	714025	603351125	29.0688837	9.4540719	.001183432
846	715716	605495736	29.0860791	9.4577999	.001182033
847	717409	607645423	29.1032644	9.4615249	.001180638
848	719104	609800192	29.1204396	9.4652470	.001179245
849	720801	611960049	29.1376046	9.4689661	.001177856
850	722500	614125000	29.1547595	9.4726824	.001176471
851	724201	616295051	29.1719043	9.4763957	.001175088
852	725904	618470208	29.1890390	9.4801061	.001173709
853	727609	620650477	29.2061637	9.4838136	.001172333
854	729316	622835864	29.2232784	9.4875182	.001170960
855	731025	625026375	29.2403830	9.4912200	.001169591
856	732736	627222016	29.2574777	9.4949188	.001168224
857	734449	629422793	29.2745623	9.4986147	.001166861
858	736164	631628712	29.2916370	9.5023078	.001165501
859	737881	633839779	29.3087018	9.5059980	.001164144
860	739600	636056000	29.3257566	9.5096854	.001162791
861	741321	638277381	29.3428015	9.5133699	.001161440
862	743044	640503928	29.3598365	9.5170515	.001160093
863	744769	642735647	29.3768616	9.5207303	.001158749
864	746496	644972544	29.3938769	9.5244063	.001157407
865	748225	647214625	29.4108823	9.5280794	.001156069
866	749956	649461896	29.4278779	9.5317497	.0011547
867	751689	651714363	29.4448637	9.5354172	.0011
868	753424	653972032	29.4618397	9.5390818	.001

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
869	755161	656234909	29.4788059	9.5427437	.001150748
870	756900	658503000	29.4957624	9.5464027	.001149425
871	758641	660776311	29.5127091	9.5500589	.001148106
872	760384	663054848	29.5296461	9.5537123	.001146789
873	762129	665338617	29.5465734	9.5573630	.001145475
874	763876	667627624	29.5634910	9.5610108	.001144165
875	765625	669921875	29.5803989	9.5646559	.001142857
876	767376	672221376	29.5972972	9.5682982	.001141553
877	769129	674526133	29.6141858	9.5719377	.001140251
878	770884	676836152	29.6310648	9.5755745	.001138952
879	772641	679151439	29.6479342	9.5792085	.001137656
880	774400	681472000	29.6647939	9.5828397	.001136364
881	776161	683797841	29.6816442	9.5864682	.001135074
882	777924	686128968	29.6984848	9.5900939	.001133787
883	779689	688465387	29.7153159	9.5937169	.001132503
884	781456	690807104	29.7321375	9.5973373	.001131222
885	783225	693154125	29.7489496	9.6009548	.001129944
886	784996	695506456	29.7657521	9.6045696	.001128668
887	786769	697864103	29.7825452	9.6081817	.001127396
888	788544	700227072	29.7993289	9.6117911	.001126126
889	790321	702595369	29.8161030	9.6153977	.001124859
890	792100	704969000	29.8328678	9.6190017	.001123596
891	793881	707347971	29.8496231	9.6226030	.001122334
892	795664	709732288	29.8663690	9.6262016	.001121076
893	797449	712121957	29.8831056	9.6297975	.001119821
894	799236	714516984	29.8998328	9.6333907	.001118568
895	801025	716917375	29.9165506	9.6369812	.001117318
896	802816	719323136	29.9332591	9.6405690	.001116071
897	804609	721734273	29.9499583	9.6441542	.001114827
898	806404	724150792	29.9666481	9.6477367	.001113586
899	808201	726572699	29.9833287	9.6513166	.001112347
900	810000	729000000	30.0000000	9.6548938	.001111111
901	811801	731432701	30.0166620	9.6584684	.001109878
902	813604	733870808	30.0333148	9.6620403	.001108647
903	815409	736314327	30.0499584	9.6656096	.001107420
904	817216	738763264	30.0665928	9.6691762	.001106195
905	819025	741217625	30.0832179	9.6727403	.001104972
906	820836	743677416	30.0998339	9.6763017	.001103753
907	822649	746142643	30.1164407	9.6798604	.001102536
908	824464	748613312	30.1330383	9.6834166	.001101322
909	826281	751089429	30.1496269	9.6869701	.001100110
910	828100	753571000	30.1662063	9.6905211	.001098901
911	829921	756058031	30.1827765	9.6940694	.001097695
912	831744	758550528	30.1993377	9.6976151	.001096491
913	833569	761048497	30.2158899	9.7011583	.001095290
914	835396	763551944	30.2324329	9.7046989	.001094092
915	837225	766060875	30.2489669	9.7082369	.001092896
916	839056	768575296	30.2654919	9.7117723	.001091703
917	840889	771095213	30.2820079	9.7153051	.001090513
918	842724	773620632	30.2985148	9.7188354	.001089325
919	844561	776151559	30.3150128	9.7223631	.001088139
920	846400	778688000	30.3315018	9.7258883	.001086957
921	848241	781229961	30.3479818	9.7294109	.001085776
922	850084	783777448	30.3644529	9.7329309	.001084599
923	851929	786330467	30.3809151	9.7364484	.001083424
924	853776	788889024	30.3973683	9.7399634	.001082251
925	855625	791453125	30.4138127	9.7434758	.001081081
926	857476	794022776	30.4302481	9.7469857	.001079914
927	859329	796597983	30.4466747	9.7504930	.001078749
928	861184	799178752	30.4630924	9.7539979	.001077586
[illegible]	863041	801765089	30.4795013	9.7575002	.001076426
[illegible]	864900	804357000	30.4959014	9.7610001	.001075269

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
931	866761	806954491	30.5122926	9.7644974	.001074114
932	868624	809557568	30.5286750	9.7679922	.001072961
933	870489	812166237	30.5450487	9.7714845	.001071811
934	872356	814780504	30.5614136	9.7749743	.001070664
935	874225	817400375	30.5777697	9.7784616	.001069519
936	876096	820025856	30.5941171	9.7819466	.001068376
937	877969	822656953	30.6104557	9.7854288	.001067236
938	879844	825293672	30.6267857	9.7889087	.001066098
939	881721	827936019	30.6431069	9.7923861	.001064963
940	883600	830584000	30.6594194	9.7958611	.001063830
941	885481	833237621	30.6757233	9.7993336	.001062699
942	887364	835896888	30.6920185	9.8028036	.001061571
943	889249	838561807	30.7083051	9.8062711	.001060445
944	891136	841232384	20.7245830	9.8097362	.001059322
945	893025	843908625	30.7408523	9.8131989	.001058201
946	894916	846590536	30.7571130	9.8166591	.001057082
947	896809	849278123	30.7733651	9.8201169	.001055966
948	898704	851971392	30.7896086	9.8235723	.001054852
949	900601	854670349	30.8058436	9.8270252	.001053741
950	902500	857375000	30.8220700	9.8304757	.001052632
951	904401	860085351	30.8382879	9.8339238	.001051525
952	906304	862801408	30.8544972	9.8373695	.001050420
953	908209	865523177	30.8706981	9.8408127	.001049318
954	910116	868250664	30.8868904	9.8442536	.001048218
955	912025	870983875	30.9030743	9.8476920	.001047120
956	913936	873722816	30.9192497	9.8511280	.001046025
957	915849	876467493	30.9354166	9.8545617	.001044932
958	917764	879217912	30.9515751	9.8579929	.001043841
959	919681	881974079	30.9677251	9.8614218	.001042753
960	921600	884736000	30.9838668	9.8648483	.001041667
961	923521	887503681	31.0000000	9.8682724	.001040583
962	925444	890277128	31.0161248	9.8716941	.001039501
963	927369	893056347	31.0322413	9.8751135	.001038422
964	929296	895841344	31.0483494	9.8785305	.001037344
965	931225	898632125	31.0644491	9.8819451	.001036269
966	933156	901428696	31.0805405	9.8853574	.001035197
967	935089	904231063	31.0966236	9.8887673	.001034126
968	937024	907039232	31.1126984	9.8921749	.001033058
969	938961	909853209	31.1287648	9.8955801	.001031992
970	940900	912673000	31.1448230	9.8989830	.001030928
971	942841	915498611	31.1608729	9.9023835	.001029866
972	944784	918330048	31.1769145	9.9057817	.001028807
973	946729	921167317	31.1929479	9.9091776	.001027749
974	948676	924010424	31.2089731	9.9125712	.001026694
975	950625	926859375	31.2249900	9.9159624	.001025641
976	952576	929714176	31.2409987	9.9193513	.001024590
977	954529	932574833	31.2569992	9.9227379	.001023541
978	956484	935441352	31.2729915	9.9261222	.001022495
979	958441	938313739	31.2889757	9.9295042	.001021450
980	960400	941192000	31.3049517	9.9328839	.001020408
981	962361	944076141	31.3209195	9.9362613	.001019368
982	964324	946966168	31.3368792	9.9396363	.001018330
983	966289	949862087	31.3528308	9.9430092	.001017294
984	968256	952763904	31.3687743	9.9463797	.001016260
985	970225	955671625	31.3847097	9.9497479	.001015228
986	972196	958585256	31.4006369	9 9531138	.001014199
987	974169	961504803	31.4165561	9.9564775	.001013171
988	976144	964430272	31.4324673	9.9598389	.001012146
989	978121	967361669	31.4483704	9.9631981	.001011122
990	980100	970299000	31.4642654	9.9665549	.001010101
991	982081	973242271	31.4801525	9.9699095	.001009082
992	984064	976191488	31.4960315	9.9732619	.001008065

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
993	986049	979146657	31.5119025	9.9766120	.001007049
994	988036	982107784	31.5277655	9.9799599	.001006036
995	990025	985074875	31.5436206	9.9833055	.001005025
996	992016	988047936	31.5594677	9.9866488	.001004016
997	994009	991026973	31.5753068	9.9899900	.001003009
998	996004	994011992	31.5911380	9.9933289	.001002004
999	998001	997002999	31.6069613	9.9966656	.001001001
1000	1000000	1000000000	31.6227766	10.0000000	.001000000
1001	1002001	1003003001	31.6385840	10.0033322	.0009990010
1002	1004004	1006012008	31.6543836	10.0066622	.0009980040
1003	1006009	1009027027	31.6701752	10.0099899	.0009970090
1004	1008016	1012048064	31.6859590	10.0133155	.0009960159
1005	1010025	1015075125	31.7017349	10.0166389	.0009950249
1006	1012036	1018108216	31.7175030	10.0199601	.0009940358
1007	1014049	1021147343	31.7332633	10.0232791	.0009930487
1008	1016064	1024192512	31.7490157	10.0265958	.0009920635
1009	1018081	1027243729	31.7647603	10.0299104	.0009910803
1010	1020100	1030301000	31.7804972	10.0332228	.0009900990
1011	1022121	1033364331	31.7962262	10.0365330	.0009891197
1012	1024144	1036433728	31.8119474	10.0398410	.0009881423
1013	1026169	1039509197	31.8276609	10.0431469	.0009871668
1014	1028196	1042590744	31.8433666	10.0464506	0009861933
1015	1030225	1045678375	31.8590646	10.0497521	.0009852217
1016	1032256	1048772096	31.8747549	10.0530514	.0009842520
1017	1034289	1051871913	31.8904374	10.0563485	.0009832842
1018	1036324	1054977832	31.9061123	10.0596435	.0009823183
1019	1038361	1058089859	31.9217794	10.0629364	.0009813543
1020	1040400	1061208000	31.9374388	10.0662271	.0009803922
1021	1042441	1064332261	31.9530906	10.0695156	.0009794319
1022	1044484	1067462648	31.9687347	10.0728020	.0009784736
1023	1046529	1070599167	31.9843712	10.0760863	.0009775171
1024	1048576	1073741824	32.0000000	10.0793684	.0009765625
1025	1050625	1076890625	32.0156212	10.0826484	.0009756098
1026	1052676	1080045576	32.0312348	10.0859262	.0009746589
1027	1054729	1083206683	32.0468407	10.0892019	.0009737098
1028	1056784	1086373952	32.0624391	10.0924755	.0009727626
1029	1058841	1089547389	32.0780298	10.0957469	.0009718173
1030	1060900	1092727000	32.0936131	10.0990163	.0009708738
1031	1062961	1095912791	32.1091887	10.1022835	.0009699321
1032	1065024	1099104768	32.1247568	10.1055487	.0009689922
1033	1067089	1102302937	32.1403173	10.1088117	.0009680542
1034	1069156	1105507304	32.1558704	10.1120726	.0009671180
1035	1071225	1108717875	32.1714159	10.1153314	.0009661836
1036	1073296	1111934656	32.1869539	10.1185882	.0009652510
1037	1075369	1115157653	32.2024844	10.1218428	.0009643202
1038	1077444	1118386872	32.2180074	10.1250953	.0009633911
1039	1079521	1121622319	32.2335229	10.1283457	.0009624639
1040	1081600	1124864000	32.2490310	10.1315941	.0009615385
1041	1083681	1128111921	32.2645316	10.1348403	.0009606148
1042	1085764	1131366088	32.2800248	10.1380845	.0009596929
1043	1087849	1134626507	32.2955105	10.1413266	.0009587728
1044	1089936	1137893184	32.3109888	10.1445667	.0009578544
1045	1092025	1141166125	32.3264598	10.1478047	.0009569378
1046	1094116	1144445336	32.3419233	10.1510406	.0009560229
1047	1096209	1147730823	32.3573794	10.1542744	.0009551098
1048	1098304	1151022592	32.3728281	10.1575062	.0009541985
1049	1100401	1154320649	32.3882695	10.1607359	.0009532888
1050	1102500	1157625000	32.4037035	10.1639636	.0009523810
1051	*1104601*	1160935651	32.4191301	10.1671893	.0009514748
[illegible]	*1106704*	1164252608	32.4345495	10.1704129	.0009505703
[illegible]	*1108809*	1167575877	32.4499615	10.1736344	.0009496676
	1110916	1170905464	32.4653662	10.1768539	.0009487666

No. 120 L. 079.] [No. 134 L. 130.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
120	079181	9543	9904	0266	0626	0987	1347	1707	2067	2426	360
1	082785	3144	3503	3861	4219	4576	4934	5291	5647	6004	357
2	6360	6716	7071	7426	7781	8136	8490	8845	9198	9552	355
3	9905	0258	0611	0963	1315	1667	2018	2370	2721	3071	352
4	093422	3772	4122	4471	4820	5169	5518	5866	6215	6562	349
5	6910	7257	7604	7951	8298	8644	8990	9335	9681	0026	346
6	100371	0715	1059	1403	1747	2091	2434	2777	3119	3462	343
7	3804	4146	4487	4828	5169	5510	5851	6191	6531	6871	341
8	7210	7549	7888	8227	8565	8903	9241	9579	9916	0253	338
9	110590	0926	1263	1599	1934	2270	2605	2940	3275	3609	335
130	3943	4277	4611	4944	5278	5611	5943	6276	6608	6940	333
1	7271	7603	7934	8265	8595	8926	9256	9586	9915	0245	330
2	120574	0903	1231	1560	1888	2216	2544	2871	3198	3525	328
3	3852	4178	4504	4830	5156	5481	5806	6131	6456	6781	325
4	7105	7429	7753	8076	8399	8722	9045	9368	9690	0012	323
	13										

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
355	35.5	71.0	106.5	142.0	177.5	213.0	248.5	284.0	319.5
354	35.4	70.8	106.2	141.6	177.0	212.4	247.8	283.2	318.6
353	35.3	70.6	105.9	141.2	176.5	211.8	247.1	282.4	317.7
352	35.2	70.4	105.6	140.8	176.0	211.2	246.4	281.6	316.8
351	35.1	70.2	105.3	140.4	175.5	210.6	245.7	280.8	315.9
350	35.0	70.0	105.0	140.0	175.0	210.0	245.0	280.0	315.0
349	34.9	69.8	104.7	139.6	174.5	209.4	244.3	279.2	314.1
348	34.8	69.6	104.4	139.2	174.0	208.8	243.6	278.4	313.2
347	34.7	69.4	104.1	138.8	173.5	208.2	242.9	277.6	312.3
346	34.6	69.2	103.8	138.4	173.0	207.6	242.2	276.8	311.4
345	34.5	69.0	103.5	138.0	172.5	207.0	241.5	276.0	310.5
344	34.4	68.8	103.2	137.6	172.0	206.4	240.8	275.2	309.6
343	34.3	68.6	102.9	137.2	171.5	205.8	240.1	274.4	308.7
342	34.2	68.4	102.6	136.8	171.0	205.2	239.4	273.6	307.8
341	34.1	68.2	102.3	136.4	170.5	204.6	238.7	272.8	306.9
340	34.0	68.0	102.0	136.0	170.0	204.0	238.0	272.0	306.0
339	33.9	67.8	101.7	135.6	169.5	203.4	237.3	271.2	305.1
338	33.8	67.6	101.4	135.2	169.0	202.8	236.6	270.4	304.2
337	33.7	67.4	101.1	134.8	168.5	202.2	235.9	269.6	303.3
336	33.6	67.2	100.8	134.4	168.0	201.6	235.2	268.8	302.4
335	33.5	67.0	100.5	134.0	167.5	201.0	234.5	268.0	301.5
334	33.4	66.8	100.2	133.6	167.0	200.4	233.8	267.2	300.6
333	33.3	66.6	99.9	133.2	166.5	199.8	233.1	266.4	299.7
332	33.2	66.4	99.6	132.8	166.0	199.2	232.4	265.6	298.8
331	33.1	66.2	99.3	132.4	165.5	198.6	231.7	264.8	297.9
330	33.0	66.0	99.0	132.0	165.0	198.0	231.0	264.0	297.0
329	32.9	65.8	98.7	131.6	164.5	197.4	230.3	263.2	296.1
328	32.8	65.6	98.4	131.2	164.0	196.8	229.6	262.4	295.2
327	32.7	65.4	98.1	130.8	163.5	196.2	228.9	261.6	294.3
326	32.6	65.2	97.8	130.4	163.0	195.6	228.2	260.8	293.4
325	32.5	65.0	97.5	130.0	162.5	195.0	227.5	260.0	292.5
324	32.4	64.8	97.2	129.6	162.0	194.4	226.8	259.2	291.
323	32.3	64.6	96.9	129.2	161.5	193.8	226.1	258.4	290
322	32.2	64.4	96.6	128.8	161.0	193.2	225.4	257.6	28

No. 135 L. 130.] [No. 149 L. 175.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
135	130334	0655	0977	1298	1619	1939	2260	2580	2900	3219	321
6	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403	318
7	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564	316
8	9879	0194	0508	0822	1136	1450	1763	2076	2389	2702	314
9	143015	3327	3639	3951	4263	4574	4885	5196	5507	5818	311
140	6128	6438	6748	7058	7367	7676	7985	8294	8603	8911	309
1	9219	9527	9835	0142	0449	0756	1063	1370	1676	1982	307
2	152288	2594	2900	3205	3510	3815	4120	4424	4728	5032	305
3	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	303
4	8362	8664	8965	9266	9567	9868	0168	0469	0769	1068	301
5	161368	1667	1967	2266	2564	2863	3161	3460	3758	4055	299
6	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	297
7	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	295
8	170262	0555	0848	1141	1434	1726	2019	2311	2603	2895	293
9	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
321	32.1	64.2	96.3	128.4	160.5	192.6	224.7	256.8	288.9
320	32.0	64.0	96.0	128.0	160.0	192.0	224.0	256.0	288.0
319	31.9	63.8	95.7	127.6	159.5	191.4	223.3	255.2	287.1
318	31.8	63.6	95.4	127.2	159.0	190.8	222.6	254.4	286.2
317	31.7	63.4	95.1	126.8	158.5	190.2	221.9	253.6	285.3
316	31.6	63.2	94.8	126.4	158.0	189.6	221.2	252.8	284.4
315	31.5	63.0	94.5	126.0	157.5	189.0	220.5	252.0	283.5
314	31.4	62.8	94.2	125.6	157.0	188.4	219.8	251.2	282.6
313	31.3	62.6	93.9	125.2	156.5	187.8	219.1	250.4	281.7
312	31.2	62.4	93.6	124.8	156.0	187.2	218.4	249.6	280.8
311	31.1	62.2	93.3	124.4	155.5	186.6	217.7	248.8	279.9
310	31.0	62.0	93.0	124.0	155.0	186.0	217.0	248.0	279.0
309	30.9	61.8	92.7	123.6	154.5	185.4	216.3	247.2	278.1
308	30.8	61.6	92.4	123.2	154.0	184.8	215.6	246.4	277.2
307	30.7	61.4	92.1	122.8	153.5	184.2	214.9	245.6	276.3
306	30.6	61.2	91.8	122.4	153.0	183.6	214.2	244.8	275.4
305	30.5	61.0	91.5	122.0	152.5	183.0	213.5	244.0	274.5
304	30.4	60.8	91.2	121.6	152.0	182.4	212.8	243.2	273.6
303	30.3	60.6	90.9	121.2	151.5	181.8	212.1	242.4	272.7
302	30.2	60.4	90.6	120.8	151.0	181.2	211.4	241.6	271.8
301	30.1	60.2	90.3	120.4	150.5	180.6	210.7	240.8	270.9
300	30.0	60.0	90.0	120.0	150.0	180.0	210.0	240.0	270.0
299	29.9	59.8	89.7	119.6	149.5	179.4	209.3	239.2	269.1
298	29.8	59.6	89.4	119.2	149.0	178.8	208.6	238.4	268.2
297	29.7	59.4	89.1	118.8	148.5	178.2	207.9	237.6	267.3
296	29.6	59.2	88.8	118.4	148.0	177.6	207.2	236.8	266.4
295	29.5	59.0	88.5	118.0	147.5	177.0	206.5	236.0	265.5
294	29.4	58.8	88.2	117.6	147.0	176.4	205.8	235.2	264.6
293	29.3	58.6	87.9	117.2	146.5	175.8	205.1	234.4	263.7
292	29.2	58.4	87.6	116.8	146.0	175.2	204.4	233.6	262.8
291	29.1	58.2	87.3	116.4	145.5	174.6	203.7	232.8	261.9
290	29.0	58.0	87.0	116.0	145.0	174.0	203.0	232.0	261.0
289	28.9	57.8	86.7	115.6	144.5	173.4	202.3	231.2	260.1
288	28.8	57.6	86.4	115.2	144.0	172.8	201.6	230.4	259.2
287	28.7	57.4	86.1	114.8	143.5	172.2	200.9	229.6	258.3
	28.6	57.2	85.8	114.4	143.0	171.6	200.2	228.8	257.4

No. 150 L. 176.] [No. 169 L. 230.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
150	176091	6381	6670	6959	7248	7536	7825	8113	8401	8689	289
1	8977	9264	9552	9839	0126	0413	0699	0986	1272	1558	287
2	181844	2129	2415	2700	2985	3270	3555	3839	4123	4407	285
3	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
4	7521	7803	8084	8366	8647	8928	9209	9490	9771	0051	281
5	190332	0612	0892	1171	1451	1730	2010	2289	2567	2846	279
6	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
7	5900	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
8	8657	8932	9206	9481	9755	0029	0303	0577	0850	1124	274
9	201397	1670	1943	2216	2488	2761	3033	3305	3577	3848	272
160	4120	4391	4663	4934	5204	5475	5746	6016	6286	6556	271
1	6826	7096	7365	7634	7904	8173	8441	8710	8979	9247	269
2	9515	9783	0051	0319	0586	0853	1121	1388	1654	1921	267
3	212188	2454	2720	2986	3252	3518	3783	4049	4314	4579	266
4	4844	5109	5373	5638	5902	6166	6430	6694	6957	7221	264
5	7484	7747	8010	8273	8536	8798	9060	9323	9585	9846	262
6	220108	0370	0631	0892	1153	1414	1675	1936	2196	2456	261
7	2716	2976	3236	3496	3755	4015	4274	4533	4792	5051	259
8	5309	5568	5826	6084	6342	6600	6858	7115	7372	7630	258
9	7887 23	8144	8400	8657	8913	9170	9426	9682	9938	0193	256

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
285	28.5	57.0	85.5	114.0	142.5	171.0	199.5	228.0	256.5
284	28.4	56.8	85.2	113.6	142.0	170.4	198.8	227.2	255.6
283	28.3	56.6	84.9	113.2	141.5	169.8	198.1	226.4	254.7
282	28.2	56.4	84.6	112.8	141.0	169.2	197.4	225.6	253.8
281	28.1	56.2	84.3	112 4	140.5	168.6	196.7	224.8	252.9
280	28.0	56.0	84.0	112.0	140.0	168.0	196.0	224.0	252.0
279	27.9	55.8	83.7	111.6	139.5	167.4	195.3	223.2	251.1
278	27.8	55.6	83.4	111.2	139.0	166.8	194.6	222.4	250.2
277	27.7	55.4	83.1	110.8	138.5	166.2	193.9	221.6	249.3
276	27.6	55.2	82.8	110.4	138.0	165.6	193.2	220.8	248.4
275	27.5	55.0	82.5	110.0	137.5	165.0	192.5	220.0	247.5
274	27.4	54.8	82.2	109.6	137.0	164.4	191.8	219.2	246.6
273	27.3	54.6	81.9	109.2	136.5	163.8	191.1	218.4	245.7
272	27.2	54.4	81.6	108.8	136.0	163.2	190.4	217.6	244.8
271	27.1	54.2	81.3	108.4	135.5	162.6	189.7	216.8	243.9
270	27.0	54.0	81.0	108.0	135.0	162.0	189.0	216.0	243.0
269	26.9	53.8	80.7	107.6	134.5	161.4	188.3	215.2	242.1
268	26.8	53.6	80.4	107.2	134.0	160.8	187.6	214.4	241.2
267	26.7	53.4	80.1	106.8	133.5	160.2	186.9	213.6	240.3
266	26.6	53.2	79.8	106.4	133.0	159.6	186.2	212.8	239.4
265	26.5	53.0	79.5	106.0	132.5	159.0	185.5	212.0	238.5
264	26.4	52.8	79.2	105.6	132.0	158.4	184.8	211.2	237.6
263	26.3	52.6	78.9	105.2	131.5	157.8	184.1	210.4	236.7
262	26.2	52.4	78.6	104.8	131.0	157.2	183.4	209.6	235.8
261	26.1	52.2	78.3	104.4	130.5	156.6	182.7	208.8	234.9
260	26.0	52.0	78.0	104.0	130.0	156.0	182.0	208.0	234.0
259	25.9	51.8	77.7	103.6	129.5	155.4	181.3	207.2	233.1
258	25.8	51.6	77.4	103.2	129.0	154.8	180.6	206.4	232.2
257	25.7	51.4	77.1	102.8	128.5	154.2	179.9	205.6	231.3
256	25.6	51.2	76.8	102.4	128.0	153.6	179.2	204.8	230
255	25.5	51.0	76.5	102.0	127.5	153.0	178.5	204.0	[illegible]

N.	0	1	2	3	4	5	6	7	8	9	Diff.
170	230449	0704	0960	1215	1470	1724	1979	2234	2488	2742	255
1	2996	3250	3504	3757	4011	4264	4517	4770	5023	5276	253
2	5528	5781	6033	6285	6537	6789	7041	7292	7544	7795	252
3	8046	8297	8548	8799	9049	9299	9550	9800	0050	0300	250
4	240549	0799	1048	1297	1546	1795	2044	2293	2541	2790	249
5	3038	3286	3534	3782	4030	4277	4525	4772	5019	5266	248
6	5513	5759	6006	6252	6499	6745	6991	7237	7482	7728	246
7	7973	8219	8464	8709	8954	9198	9443	9687	9932	0176	245
8	250420	0664	0908	1151	1395	1638	1881	2125	2368	2610	243
9	2853	3096	3338	3580	3822	4064	4306	4548	4790	5031	242
180	5273	5514	5755	5996	6237	6477	6718	6958	7198	7439	241
1	7679	7918	8158	8398	8637	8877	9116	9355	9594	9833	239
2	260071	0310	0548	0787	1025	1263	1501	1739	1976	2214	238
3	2451	2688	2925	3162	3399	3636	3873	4109	4346	4582	237
4	4818	5054	5290	5525	5761	5996	6232	6467	6702	6937	235
5	7172	7406	7641	7875	8110	8344	8578	8812	9046	9279	234
6	9513	9746	9980	0213	0446	0679	0912	1144	1377	1609	233
7	271842	2074	2306	2538	2770	3001	3233	3464	3696	3927	232
8	4158	4389	4620	4850	5081	5311	5542	5772	6002	6232	230
9	6462	6692	6921	7151	7380	7609	7838	8067	8296	8525	229

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
255	25.5	51.0	76.5	102.0	127.5	153.0	178.5	204.0	229.5
254	25.4	50.8	76.2	101.6	127.0	152.4	177.8	203.2	228.6
253	25.3	50.6	75.9	101.2	126.5	151.8	177.1	202.4	227.7
252	25.2	50.4	75.6	100.8	126.0	151.2	176.4	201.6	226.8
251	25.1	50.2	75.3	100.4	125.5	150.6	175.7	200.8	225.9
250	25 0	50.0	75.0	100.0	125.0	150.0	175.0	200.0	225.0
249	24.9	49.8	74.7	99.6	124.5	149.4	174.3	199.2	224.1
248	24.8	49.6	74.4	99.2	124.0	148.8	173.6	198.4	223.2
247	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3
246	24.6	49.2	73.8	98.4	123.0	147.6	172.2	196.8	221.4
245	24.5	49.0	73.5	98.0	122.5	147.0	171.5	196.0	220.5
244	24.4	48.8	73.2	97.6	122.0	146.4	170.8	195.2	219.6
243	24.3	48.6	72.9	97.2	121.5	145.8	170.1	194.4	218.7
242	24.2	48.4	72.6	96.8	121.0	145.2	169.4	193.6	217.8
241	24.1	48.2	72.3	96.4	120.5	144.6	168.7	192.8	216.9
240	24.0	48.0	72.0	96.0	120.0	144.0	168.0	192.0	216.0
239	23.9	47.8	71.7	95.6	119.5	143.4	167.3	191.2	215.1
238	23.8	47.6	71.4	95.2	119.0	142.8	166.6	190.4	214.2
237	23.7	47.4	71.1	94.8	118.5	142.2	165.9	189.6	213.3
236	23.6	47.2	70.8	94.4	118.0	141.6	165.2	188.8	212.4
235	23.5	47.0	70.5	94.0	117.5	141.0	164.5	188.0	211.5
234	23.4	46.8	70.2	93.6	117.0	140.4	163.8	187.2	210.6
233	23.3	46.6	69.9	93.2	116.5	139.8	163.1	186.4	209.7
232	23.2	46.4	69.6	92.8	116.0	139.2	162.4	185.6	208.8
231	23.1	46.2	69.3	92.4	115.5	138.6	161.7	184.8	207.9
230	23.0	46.0	69.0	92.0	115.0	138.0	161.0	184.0	207.0
[illegible]	22.9	45.8	68.7	91.6	114.5	137.4	160.3	183.2	206.1
[illegible]	22.8	45.6	68.4	91.2	114.0	136.8	159.6	182.4	205.2
	22.7	45.4	68.1	90.8	113.5	136.2	158.9	181.6	204.3
	22.6	45.2	67.8	90.4	113.0	135.6	158.2	180.8	203.4

0	1	2	3	4	5	6	7	8	9	Diff.
278754	8982	9211	9439	9667	9895	0123	0351	0578	0806	228
281033	1261	1488	1715	1942	2169	2396	2622	2849	3075	227
3301	3527	3753	3979	4205	4431	4656	4882	5107	5332	226
5557	5782	6007	6232	6456	6681	6905	7130	7354	7578	225
7802	8026	8249	8473	8696	8920	9143	9366	9589	9812	223
290035	0257	0480	0702	0925	1147	1369	1591	1813	2034	222
2256	2478	2699	2920	3141	3363	3584	3804	4025	4246	221
4466	4687	4907	5127	5347	5567	5787	6007	6226	6446	220
6665	6884	7104	7323	7542	7761	7979	8198	8416	8635	219
8853	9071	9289	9507	9725	9943	0161	0378	0595	0813	218
301030	1247	1464	1681	1898	2114	2331	2547	2764	2980	217
3196	3412	3628	3844	4059	4275	4491	4706	4921	5136	216
5351	5566	5781	5996	6211	6425	6639	6854	7068	7282	215
7496	7710	7924	8137	8351	8564	8778	8991	9204	9417	213
9630	9843	0056	0268	0481	0693	0906	1118	1330	1542	212
311754	1966	2177	2389	2600	2812	3023	3234	3445	3656	211
3867	4078	4289	4499	4710	4920	5130	5340	5551	5760	210
5970	6180	6390	6599	6809	7018	7227	7436	7646	7854	209
8063	8272	8481	8689	8898	9106	9314	9522	9730	9938	208
320146	0354	0562	0769	0977	1184	1391	1598	1805	2012	207
2219	2426	2633	2839	3046	3252	3458	3665	3871	4077	206
4282	4488	4694	4899	5105	5310	5516	5721	5926	6131	205
6336	6541	6745	6950	7155	7359	7563	7767	7972	8176	204
8380	8583	8787	8991	9194	9398	9601	9805	0008	0211	203
330414	0617	0819	1022	1225	1427	1630	1832	2034	2236	202

PROPORTIONAL PARTS.

1	2	3	4	5	6	7	8	9
22.5	45.0	67.5	30.0	112.5	135.0	157.5	180.0	202.5
22.4	44.8	67.2	89.6	112.0	134.4	156.8	179.2	201.6
22.3	44.6	66.9	89.2	111.5	133.8	156.1	178.4	200.7
22.2	44.4	66.6	88.8	111.0	133.2	155.4	177.6	199.8
22.1	44.2	66.3	88.4	110.5	132.6	154.7	176.8	198.9
22.0	44.0	66.0	88.0	110.0	132.0	154.0	176.0	198.0
21.9	43.8	65.7	87.6	109.5	131.4	153.3	175.2	197.1
21.8	43.6	65.4	87.2	109.0	130.8	152.6	174.4	196.2
21.7	43.4	65.1	86.8	108.5	130.2	151.9	173.6	195.3
21.6	43.2	64.8	86.4	108.0	129.6	151.2	172.8	194.4
21.5	43.0	64.5	86.0	107.5	129.0	150.5	172.0	193.5
21.4	42.8	64.2	85.6	107.0	128.4	149.8	171.2	192.6
21.3	42.6	63.9	85.2	106.5	127.8	149.1	170.4	191.7
21.2	42.4	63.6	84.8	106.0	127.2	148.4	169.6	190.8
21.1	42.2	63.3	84.4	105.5	126.6	147.7	168.8	189.9
21.0	42.0	63.0	84.0	105.0	126.0	147.0	168.0	189.0
20.9	41.8	62.7	83.6	104.5	125.4	146.3	167.2	188.1
20.8	41.6	62.4	83.2	104.0	124.8	145.6	166.4	187.2
20.7	41.4	62.1	82.8	103.5	124.2	144.9	165.6	186.3
20.6	41.2	61.8	82.4	103.0	123.6	144.2	161.8	185.4
20.5	41.0	61.5	82.0	102.5	123.0	143.5	164.0	184.5
20.4	40.8	61.2	81.6	102.0	122.4	142.8	163.2	183.6
20.3	40.6	60.9	81.2	101.5	121.8	142.1	162.4	182.7
20.2	40.4	60.6	0.8	101.0	121.2	141.4	161.6	181.8

N.	0	1	2	3	4	5	6	7	8	9	Diff.
215	332438	2640	2842	3044	3246	3447	3649	3850	4051	4253	202
6	4454	4655	4856	5057	5257	5458	5658	5859	6059	6260	201
7	6460	6660	6860	7060	7260	7459	7659	7858	8058	8257	200
8	8456	8656	8855	9054	9253	9451	9650	9849	0047	0246	199
9	340444	0642	0841	1039	1237	1435	1632	1830	2028	2225	198
220	2423	2620	2817	3014	3212	3409	3606	3802	3999	4196	197
1	4392	4589	4785	4981	5178	5374	5570	5766	5962	6157	196
2	6353	6549	6744	6939	7135	7330	7525	7720	7915	8110	195
3	8305	8500	8694	8889	9083	9278	9472	9666	9860	0054	194
4	350248	0442	0636	0829	1023	1216	1410	1603	1796	1989	193
5	2183	2375	2568	2761	2954	3147	3339	3532	3724	3916	193
6	4108	4301	4493	4685	4876	5068	5260	5452	5643	5834	192
7	6026	6217	6408	6599	6790	6981	7172	7363	7554	7744	191
8	7935	8125	8316	8506	8696	8886	9076	9266	9456	9646	190
9	9835	0025	0215	0404	0593	0783	0972	1161	1350	1539	189
230	361728	1917	2105	2294	2482	2671	2859	3048	3236	3424	188
1	3612	3800	3988	4176	4363	4551	4739	4926	5113	5301	188
2	5488	5675	5862	6049	6236	6423	6610	6796	6983	7169	187
3	7356	7542	7729	7915	8101	8287	8473	8659	8845	9030	186
4	9216	9401	9587	9772	9958	0143	0328	0513	0698	0883	185
5	371068	1253	1437	1622	1806	1991	2175	2360	2544	2728	184
6	2912	3096	3280	3464	3647	3831	4015	4198	4382	4565	184
7	4748	4932	5115	5298	5481	5664	5846	6029	6212	6394	183
8	6577	6759	6942	7124	7306	7488	7670	7852	8034	8216	182
9	8398	8580	8761	8943	9124	9306	9487	9668	9849	0030	181
	38										

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
202	20.2	40.4	60.6	80.8	101.0	121.2	141.4	161.6	181.8
201	20.1	40.2	60.3	80.4	100.5	120.6	140.7	160.8	180.9
200	20.0	40.0	60.0	80.0	100.0	120.0	140.0	160.0	180.0
199	19.9	39.8	59.7	79.6	99.5	119.4	139.3	159.2	179.1
198	19.8	39.6	59.4	79.2	99.0	118.8	138.6	158.4	178.2
197	19.7	39.4	59.1	78.8	98.5	118.2	137.9	157.6	177.3
196	19.6	39.2	58.8	78.4	98.0	117.6	137.2	156.8	176.4
195	19.5	39.0	58.5	78.0	97.5	117.0	136.5	156.0	175.5
194	19.4	38.8	58.2	77.6	97.0	116.4	135.8	155.2	174.6
193	19.3	38.6	57.9	77.2	96.5	115.8	135.1	154.4	173.7
192	19.2	38.4	57.6	76.8	96.0	115.2	134.4	153.6	172.8
191	19.1	38.2	57.3	76.4	95.5	114.6	133.7	152.8	171.9
190	19.0	38.0	57.0	76.0	95.0	114.0	133.0	152.0	171.0
189	18.9	37.8	56.7	75.6	94.5	113.4	132.3	151.2	170.1
188	18.8	37.6	56.4	75.2	94.0	112.8	131.6	150.4	169.2
187	18.7	37 4	56.1	74.8	93.5	112.2	130.9	149.6	168.3
186	18.6	37.2	55.8	74.4	93.0	111.6	130.2	148.8	167.4
185	18.5	37.0	55.5	74.0	92.5	111.0	129.5	148.0	166.5
184	18.4	36.8	55.2	73.6	92.0	110.4	128.8	147.2	165.6
183	18.3	36.6	54.9	73.2	91.5	109.8	128.1	146.4	164.7
182	18.2	36.4	54.6	72.8	91.0	109.2	127.4	145.6	163.8
181	18.1	36.2	54.3	72.4	90.5	108.6	126.7	144.8	162.9
180	18.0	36.0	54.0	72.0	90.0	108.0	126.0	144.0	162.0
179	17.9	35.8	53.7	71.6	89.5	107.4	125.3	143.2	161.1

0	1	2	3	4	5	6	7	8	9	Diff.
380211	0392	0573	0754	0934	1115	1296	1476	1656	1837	181
2017	2197	2377	2557	2737	2917	3097	3277	3456	3636	180
3815	3995	4174	4353	4533	4712	4891	5070	5249	5428	179
5606	5785	5964	6142	6321	6499	6677	6856	7034	7212	178
7390	7568	7746	7924	8101	8279	8456	8634	8811	8989	178
9166	9343	9520	9698	9875	0051	0228	0405	0582	0759	177
390935	1112	1288	1464	1641	1817	1993	2169	2345	2521	176
2697	2873	3048	3224	3400	3575	3751	3926	4101	4277	176
4452	4627	4802	4977	5152	5326	5501	5676	5850	6025	175
6199	6374	6548	6722	6896	7071	7245	7419	7592	7766	174
7940	8114	8287	8461	8634	8808	8981	9154	9328	9501	173
9674	9847	0020	0192	0365	0538	0711	0883	1056	1228	173
401401	1573	1745	1917	2089	2261	2433	2605	2777	2949	172
3121	3292	3464	3635	3807	3978	4149	4320	4492	4663	171
4834	5005	5176	5346	5517	5688	5858	6029	6199	6370	171
6540	6710	6881	7051	7221	7391	7561	7731	7901	8070	170
8240	8410	8579	8749	8918	9087	9257	9426	9595	9764	169
9933	0102	0271	0440	0609	0777	0946	1114	1283	1451	169
411620	1788	1956	2124	2293	2461	2629	2796	2964	3132	168
3300	3467	3635	3803	3970	4137	4305	4472	4639	4806	167
4973	5140	5307	5474	5641	5808	5974	6141	6308	6474	167
6641	6807	6973	7139	7306	7472	7638	7804	7970	8135	166
8301	8467	8633	8798	8964	9129	9295	9460	9625	9791	165
9956	0121	0286	0451	0616	0781	0945	1110	1275	1439	165
421604	1768	1933	2097	2261	2426	2590	2754	2918	3082	164
3246	3410	3574	3737	3901	4065	4228	4392	4555	4718	164
4882	5045	5208	5371	5534	5697	5860	6023	6186	6349	163
6511	6674	6836	6999	7161	7324	7486	7648	7811	7973	162
8135	8297	8459	8621	8783	8944	9106	9268	9429	9591	162
9752 43	9914	0075	0236	0398	0559	0720	0881	1042	1203	161

PROPORTIONAL PARTS.

ff.	1	2	3	4	5	6	7	8	9
8	17.8	35.6	53.4	71.2	89.0	106.8	124.6	142.4	160.2
7	17.7	35.4	53.1	70.8	88.5	106.2	123.9	141.6	159.3
6	17.6	35.2	52.8	70.4	88.0	105.6	123.2	140.8	158.4
5	17.5	35.0	52.5	70.0	87.5	105.0	122.5	140.0	157.5
4	17.4	34.8	52.2	69.6	87.0	104.4	121.8	139.2	156.6
3	17.3	34.6	51.9	69.2	86.5	103.8	121.1	138.4	155.7
2	17.2	34.4	51.6	68.8	86.0	103.2	120.4	137.6	154.8
1	17 1	34.2	51.3	68.4	85.5	102.6	119.7	136.8	153.9
0	17.0	34.0	51.0	68.0	85.0	102.0	119.0	136.0	153.0
9	16.9	33.8	50.7	67.6	84.5	101.4	118.3	135.2	152.1
8	16.8	33.6	50.4	67.2	84.0	100.8	117.6	134.4	151.2
7	16.7	33.4	50.1	66.8	83.5	100.2	116.9	133.6	150.3
6	16.6	33.2	49.8	66.4	83.0	99.6	116.2	132.8	149.4
5	16.5	33.0	49.5	66.0	82.5	99.0	115.5	132.0	148.5
4	16.4	32.8	49.2	65.6	82.0	98.4	114.8	131.2	147.6
3	16.3	32.6	48.9	65.2	81.5	97.8	114.1	130.4	146.7
2	16.2	32.4	48.5	64.8	81.0	97.2	113.4	129.6	145.8
1	16 1	32.2	48.3	64.4	80.5	96.6	112 7	128.8	144.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
270	431364	1525	1685	1846	2007	2167	2328	2488	2649	2809	161
1	2969	3130	3290	3450	3610	3770	3930	4090	4249	4409	160
2	4569	4729	4888	5048	5207	5367	5526	5685	5844	6004	159
3	6163	6322	6481	6640	6799	6957	7116	7275	7433	7592	159
4	7751	7909	8067	8226	8384	8542	8701	8859	9017	9175	158
5	9333	9491	9648	9806	9964	0122	0279	0437	0594	0752	158
6	440909	1066	1224	1381	1538	1695	1852	2009	2166	2323	157
7	2480	2637	2793	2950	3106	3263	3419	3576	3732	3889	157
8	4045	4201	4357	4513	4669	4825	4981	5137	5293	5449	156
9	5604	5760	5915	6071	6226	6382	6537	6692	6848	7003	155
280	7158	7313	7468	7623	7778	7933	8088	8242	8397	8552	155
1	8706	8861	9015	9170	9324	9478	9633	9787	9941	0095	154
2	450249	0403	0557	0711	0865	1018	1172	1326	1479	1633	154
3	1786	1940	2093	2247	2400	2553	2706	2859	3012	3165	153
4	3318	3471	3624	3777	3930	4082	4235	4387	4540	4692	153
5	4845	4997	5150	5302	5454	5606	5758	5910	6062	6214	152
6	6366	6518	6670	6821	6973	7125	7276	7428	7579	7731	152
7	7882	8033	8184	8336	8487	8638	8789	8940	9091	9242	151
8	9392	9543	9694	9845	9995	0146	0296	0447	0597	0748	151
9	460898	1048	1198	1348	1499	1649	1799	1948	2098	2248	150
290	2398	2548	2697	2847	2997	3146	3296	3445	3594	3744	150
1	3893	4042	4191	4340	4490	4639	4788	4936	5085	5234	149
2	5383	5532	5680	5829	5977	6126	6274	6423	6571	6719	149
3	6868	7016	7164	7312	7460	7608	7756	7904	8052	8200	148
4	8347	8495	8643	8790	8938	9085	9233	9380	9527	9675	148
5	9822	9969	0116	0263	0410	0557	0704	0851	0998	1145	147
6	471292	1438	1585	1732	1878	2025	2171	2318	2464	2610	146
7	2756	2903	3049	3195	3341	3487	3633	3779	3925	4071	146
8	4216	4362	4508	4653	4799	4944	5090	5235	5381	5526	146
9	5671	5816	5962	6107	6252	6397	6542	6687	6832	6976	145

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
161	16.1	32.2	48.3	64.4	80.5	96.6	112.7	128.8	144.9
160	16.0	32.0	48.0	64.0	80.0	96.0	112.0	128.0	144.0
159	15.9	31.8	47.7	63.6	79.5	95.4	111.3	127.2	143.1
158	15.8	31.6	47.4	63.2	79.0	94.8	110.6	126.4	142.2
157	15.7	31.4	47.1	62.8	78.5	94.2	109.9	125.6	141.3
156	15.6	31.2	46.8	62.4	78.0	93.6	109.2	124.8	140.4
155	15.5	31.0	46.5	62.0	77.5	93.0	108.5	124.0	139.5
154	15.4	30.8	46.2	61.6	77.0	92.4	107.8	123.2	138.6
153	15.3	30.6	45.9	61.2	76.5	91.8	107.1	122.4	137.7
152	15.2	30.4	45.6	60.8	76.0	91.2	106.4	121.6	136.8
151	15.1	30.2	45.3	60.4	75.5	90.6	105.7	120.8	135.9
150	15.0	30.0	45.0	60.0	75.0	90.0	105.0	120.0	135.0
149	14.9	29.8	44.7	59.6	74.5	89.4	104.3	119.2	134.1
148	14.8	29.6	44.4	59.2	74.0	88.8	103.6	118.4	133.2
147	14.7	29.4	44.1	58.8	73.5	88.2	102.9	117.6	132.3
146	14.6	29.2	43.8	58.4	73.0	87.6	102.2	116.8	131.4
145	14.5	29.0	43.5	58.0	72.5	87.0	101.5	116.0	130.5
144	14.4	28.8	43.2	57.6	72.0	86.4	100.8	115.2	129.6
143	*14.3*	28.6	42.9	57.2	71.5	85.8	100.1	114.4	128.7
142	*14.2*	28.4	42.6	56.8	71.0	85.2	99.4	113.6	127.8
	14.1	28.2	42.3	56.4	70.5	84.6	98.7	112.8	126.9
	14.0	28.0	42.0	56.0	70.0	84.0	98.0	112.0	126.0

300 L. 477.] [No. 339 L. 531.

0	1	2	3	4	5	6	7	8	9	Diff.
477121	7266	7411	7555	7700	7844	7989	8133	8278	8422	145
8566	8711	8855	8999	9143	9287	9431	9575	9719	9863	144
480007	0151	0294	0438	0582	0725	0869	1012	1156	1299	144
1443	1586	1729	1872	2016	2159	2302	2445	2588	2731	143
2874	3016	3159	3302	3445	3587	3730	3872	4015	4157	143
4300	4442	4585	4727	4869	5011	5153	5295	5437	5579	142
5721	5863	6005	6147	6289	6430	6572	6714	6855	6997	142
7138	7280	7421	7563	7704	7845	7986	8127	8269	8410	141
8551	8692	8833	8974	9114	9255	9396	9537	9677	9818	141
9958	0099	0239	0380	0520	0661	0801	0941	1081	1222	140
491362	1502	1642	1782	1922	2062	2201	2341	2481	2621	140
2760	2900	3040	3179	3319	3458	3597	3737	3876	4015	139
4155	4294	4433	4572	4711	4850	4989	5128	5267	5406	139
5544	5683	5822	5960	6099	6238	6376	6515	6653	6791	139
6930	7068	7206	7344	7483	7621	7759	7897	8035	8173	138
8311	8448	8586	8724	8862	8999	9137	9275	9412	9550	138
9687	9824	9962	0099	0236	0374	0511	0648	0785	0922	137
501059	1196	1333	1470	1607	1744	1880	2017	2154	2291	137
2427	2564	2700	2837	2973	3109	3246	3382	3518	3655	136
3791	3927	4063	4199	4335	4471	4607	4743	4878	5014	136
5150	5286	5421	5557	5693	5828	5964	6099	6234	6370	136
6505	6640	6776	6911	7046	7181	7316	7451	7586	7721	135
7856	7991	8126	8260	8395	8530	8664	8799	8934	9068	135
9203	9337	9471	9606	9740	9874	0009	0143	0277	0411	134
510545	0679	0813	0947	1081	1215	1349	1482	1616	1750	134
1883	2017	2151	2284	2418	2551	2684	2818	2951	3084	133
3218	3351	3484	3617	3750	3883	4016	4149	4282	4415	133
4548	4681	4813	4946	5079	5211	5344	5476	5609	5741	133
5874	6006	6139	6271	6403	6535	6668	6800	6932	7064	132
7196	7328	7460	7592	7724	7855	7987	8119	8251	8382	132
8514	8646	8777	8909	9040	9171	9303	9434	9566	9697	131
9828	9959	0090	0221	0353	0484	0615	0745	0876	1007	131
521138	1269	1400	1530	1661	1792	1922	2053	2183	2314	131
2444	2575	2705	2835	2966	3096	3226	3356	3486	3616	130
3746	3876	4006	4136	4266	4396	4526	4656	4785	4915	130
5045	5174	5304	5434	5563	5693	5822	5951	6081	6210	129
6339	6469	6598	6727	6856	6985	7114	7243	7372	7501	129
7630	7759	7888	8016	8145	8274	8402	8531	8660	8788	129
8917	9045	9174	9302	9430	9559	9687	9815	9943	0072	128
530200	0328	0456	0584	0712	0840	0968	1096	1223	1351	128

PROPORTIONAL PARTS.

	1	2	3	4	5	6	7	8	9
	13.9	27.8	41.7	55.6	69.5	83.4	97.3	111.2	125.1
	13.8	27.6	41.4	55.2	69.0	82.8	96.6	110.4	124.2
	13.7	27.4	41.1	54.8	68.5	82.2	95.9	109.6	123.3
	13.6	27.2	40.8	54.4	68.0	81.6	95.2	108.8	122.4
	13.5	27.0	40.5	54.0	67.5	81.0	94.5	108.0	121.5
	13.4	26.8	40.2	53.6	67.0	80.4	93.8	107.2	120.6
	13.3	26.6	39.9	53.2	66.5	79.8	93.1	106.4	119.7
	13.2	26.4	39.6	52.8	66.0	79.2	92.4	105.6	118.8
	13.1	26.2	39.3	52.4	65.5	78.6	91.7	104.8	117.9
	13.0	26.0	39.0	52.0	65.0	78.0	91.0	104.0	117
	12.9	25.8	38.7	51.6	64.5	77.4	90.3	103.2	
	12.8	25.6	38.4	51.2	64.0	76.8	89.6	102.4	
	12.7	25.4	38.1	50.8	63.5	76.2	88.9	101.	

No. 340 L. 531.] [No. 379 L. 579.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
340	531479	1607	1734	1862	1990	2117	2245	2372	2500	2627	128
1	2754	2882	3009	3136	3264	3391	3518	3645	3772	3899	127
2	4026	4153	4280	4407	4534	4661	4787	4914	5041	5167	127
3	5294	5421	5547	5674	5800	5927	6053	6180	6306	6432	126
4	6558	6685	6811	6937	7063	7189	7315	7441	7567	7693	126
5	7819	7945	8071	8197	8322	8448	8574	8699	8825	8951	126
6	9076	9202	9327	9452	9578	9703	9829	9954	0079	0204	125
7	540329	0455	0580	0705	0830	0955	1080	1205	1330	1454	125
8	1579	1704	1829	1953	2078	2203	2327	2452	2576	2701	125
9	2825	2950	3074	3199	3323	3447	3571	3696	3820	3944	124
350	4068	4192	4316	4440	4564	4688	4812	4936	5060	5183	124
1	5307	5431	5555	5678	5802	5925	6049	6172	6296	6419	124
2	6543	6666	6789	6913	7036	7159	7282	7405	7529	7652	123
3	7775	7898	8021	8144	8267	8389	8512	8635	8758	8881	123
4	9003	9126	9249	9371	9494	9616	9739	9861	9984	0106	123
5	550228	0351	0473	0595	0717	0840	0962	1084	1206	1328	122
6	1450	1572	1694	1816	1938	2060	2181	2303	2425	2547	122
7	2668	2790	2911	3033	3155	3276	3398	3519	3640	3762	121
8	3883	4004	4126	4247	4368	4489	4610	4731	4852	4973	121
9	5094	5215	5336	5457	5578	5699	5820	5940	6061	6182	121
360	6303	6423	6544	6664	6785	6905	7026	7146	7267	7387	120
1	7507	7627	7748	7868	7988	8108	8228	8349	8469	8589	120
2	8709	8829	8948	9068	9188	9308	9428	9548	9667	9787	120
3	9907	0026	0146	0265	0385	0504	0624	0743	0863	0982	119
4	561101	1221	1340	1459	1578	1698	1817	1936	2055	2174	119
5	2293	2412	2531	2650	2769	2887	3006	3125	3244	3362	119
6	3481	3600	3718	3837	3955	4074	4192	4311	4429	4548	119
7	4666	4784	4903	5021	5139	5257	5376	5494	5612	5730	118
8	5848	5966	6084	6202	6320	6437	6555	6673	6791	6909	118
9	7026	7144	7262	7379	7497	7614	7732	7849	7967	8084	118
370	8202	8319	8436	8554	8671	8788	8905	9023	9140	9257	117
1	9374	9491	9608	9725	9842	9959	0076	0193	0309	0426	117
2	570543	0660	0776	0893	1010	1126	1243	1359	1476	1592	117
3	1709	1825	1942	2058	2174	2291	2407	2523	2639	2755	116
4	2872	2988	3104	3220	3336	3452	3568	3684	3800	3915	116
5	4031	4147	4263	4379	4494	4610	4726	4841	4957	5072	116
6	5188	5303	5419	5534	5650	5765	5880	5996	6111	6226	115
7	6341	6457	6572	6687	6802	6917	7032	7147	7262	7377	115
8	7492	7607	7722	7836	7951	8066	8181	8295	8410	8525	115
9	8339	8754	8868	8983	9097	9212	9326	9441	9555	9669	114

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
138	12.8	25.6	38.4	51.2	64.0	76.8	89.6	102.4	115.2
148	12.7	25.4	38.1	50.8	63.5	76.2	88.9	101.6	114.3
147	12.6	25.2	37.8	50.4	63.0	75.6	88.2	100.8	113.4
146	12.5	25.0	37.5	50.0	62.5	75.0	87.5	100.0	112.5
145	14.4	24.8	37.2	49.6	62.0	74.4	86.8	99.2	111.6
144	14.3	24.6	36.9	49.2	61.5	73.8	86.1	98.4	110.7
143	[illegible]	24.4	36.6	48.8	61.0	73.2	85.4	97.6	109.8
142	[illegible]	[illegible]	36.3	48.4	60.5	72.6	84.7	96.8	108.9
[illegible]	[illegible]	[illegible]	36.0	48.0	60.0	72.0	84.0	96.0	108.0
[illegible]	[illegible]	[illegible]	35.7	47.6	59.5	71.4	83.3	95.2	107.1

N.	0	1	2	3	4	5	6	7	8	9	Dif.
380	579784	9898	0012	0126	0241	0355	0469	0583	0697	0811	114
1	580925	1039	1153	1267	1381	1495	1608	1722	1836	1950	
2	2063	2177	2291	2404	2518	2631	2745	2858	2972	3085	
3	3199	3312	3426	3539	3652	3765	3879	3992	4105	4218	
4	4331	4444	4557	4670	4783	4896	5009	5122	5235	5348	113
5	5461	5574	5686	5799	5912	6024	6137	6250	6362	6475	
6	6587	6700	6812	6925	7037	7149	7262	7374	7486	7599	
7	7711	7823	7935	8047	8160	8272	8384	8496	8608	8720	112
8	8832	8944	9056	9167	9279	9391	9503	9615	9726	9838	
9	9950	0061	0173	0284	0396	0507	0619	0730	0842	0953	
390	591065	1176	1287	1399	1510	1621	1732	1843	1955	2066	
1	2177	2288	2399	2510	2621	2732	2843	2954	3064	3175	111
2	3286	3397	3508	3618	3729	3840	3950	4061	4171	4282	
3	4393	4503	4614	4724	4834	4945	5055	5165	5276	5386	
4	5496	5606	5717	5827	5937	6047	6157	6267	6377	6487	
5	6597	6707	6817	6927	7037	7146	7256	7366	7476	7586	110
6	7695	7805	7914	8024	8134	8243	8353	8462	8572	8681	
7	8791	8900	9009	9119	9228	9337	9446	9556	9665	9774	
8	9883	9992	0101	0210	0319	0428	0537	0646	0755	0864	109
9	600973	1082	1191	1299	1408	1517	1625	1734	1843	1951	
400	2060	2169	2277	2386	2494	2603	2711	2819	2928	3036	
1	3144	3253	3361	3469	3577	3686	3794	3902	4010	4118	108
2	4226	4334	4442	4550	4658	4766	4874	4982	5089	5197	
3	5305	5413	5521	5628	5736	5844	5951	6059	6166	6274	
4	6381	6489	6596	6704	6811	6919	7026	7133	7241	7348	
5	7455	7562	7669	7777	7884	7991	8098	8205	8312	8419	107
6	8526	8633	8740	8847	8954	9061	9167	9274	9381	9488	
7	9594	9701	9808	9914	0021	0128	0234	0341	0447	0554	
8	610660	0767	0873	0979	1086	1192	1298	1405	1511	1617	
9	1723	1829	1936	2042	2148	2254	2360	2466	2572	2678	106
410	2784	2890	2996	3102	3207	3313	3419	3525	3630	3736	
1	3842	3947	4053	4159	4264	4370	4475	4581	4686	4792	
2	4897	5003	5108	5213	5319	5424	5529	5634	5740	5845	
3	5950	6055	6160	6265	6370	6476	6581	6686	6790	6895	105
4	7000	7105	7210	7315	7420	7525	7629	7734	7839	7943	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
118	11.8	23.6	35.4	47.2	59.0	70.8	82.6	94.4	106.2
117	11.7	23.4	35.1	46.8	58.5	70.2	81.9	93.6	105.3
116	11.6	23.2	34.8	46.4	58.0	69.6	81.2	92.8	104.4
115	11.5	23.0	34.5	46.0	57.5	69.0	80.5	92.0	103.5
114	11.4	22.8	34.2	45.6	57.0	68.4	79.8	91.2	102.6
113	11.3	22.6	33.9	45.2	56.5	67.8	79.1	90.4	101.7
112	11.2	22.4	33.6	44.8	56.0	67.2	78.4	89.6	100.8
111	11.1	22.2	33.3	44.4	55.5	66.6	77.7	88.8	99.9
110	11.0	22.0	33.0	44.0	55.0	66.0	77.0	88.0	99.0
109	10.9	21.8	32.7	43.6	54.5	65.4	76.3	87.2	98.1
108	10.8	21.6	32.4	43.2	54.0	64.8	75.6	86.4	97.2
107	10.7	21.4	32.1	42.8	53.5	64.2	74.9	85.6	96.3
106	10.6	21.2	31.8	42.4	53.0	63.6	74.2	84.8	95.4
105	10.5	21.0	31.5	42.0	52.5	63.0	73.5	84.0	94
104	10.4	20.8	31.2	41.6	52.0	62.4	72.8	83.2	9

N	0	1	2	3	4	5	6	7	8	9	Di
415	618048	8153	8257	8362	8466	8571	8676	8780	8884	8989	1
6	9093	9198	9302	9406	9511	9615	9719	9824	9928	0032	
7	620136	0240	0344	0448	0552	0656	0760	0864	0968	1072	1
8	1176	1280	1384	1488	1592	1695	1799	1903	2007	2110	
9	2214	2318	2421	2525	2628	2732	2835	2939	3042	3146	
420	3249	3353	3456	3559	3663	3766	3869	3973	4076	4179	
1	4282	4385	4488	4591	4695	4798	4901	5004	5107	5210	1
2	5312	5415	5518	5621	5724	5827	5929	6032	6135	6238	
3	6340	6443	6546	6648	6751	6853	6956	7058	7161	7263	
4	7366	7468	7571	7673	7775	7878	7980	8082	8185	8287	
5	8389	8491	8593	8695	8797	8900	9002	9104	9206	9308	1
6	9410	9512	9613	9715	9817	9919	0021	0123	0224	0326	
7	630428	0530	0631	0733	0835	0936	1038	1139	1241	1342	
8	1444	1545	1647	1748	1849	1951	2052	2153	2255	2356	
9	2457	2559	2660	2761	2862	2963	3064	3165	3266	3367	
430	3468	3569	3670	3771	3872	3973	4074	4175	4276	4376	1
1	4477	4578	4679	4779	4880	4981	5081	5182	5283	5383	
2	5484	5584	5685	5785	5886	5986	6087	6187	6287	6388	
3	6488	6588	6688	6789	6889	6989	7089	7189	7290	7390	
4	7490	7590	7690	7790	7890	7990	8090	8190	8290	8389	1
5	8489	8589	3689	8789	8888	8988	9088	9188	9287	9387	
6	9486	9586	9686	9785	9885	9984	0084	0183	0283	0382	
7	640481	0581	0680	0779	0879	0978	1077	1177	1276	1375	
8	1474	1573	1672	1771	1871	1970	2069	2168	2267	2366	
9	2465	2563	2662	2761	2860	2959	3058	3156	3255	3354	9
440	3453	3551	3650	3749	3847	3946	4044	4143	4242	4340	
1	4439	4537	4636	4734	4832	4931	5029	5127	5226	5324	
2	5422	5521	5619	5717	5815	5913	6011	6110	6208	6306	
3	6404	6502	6600	6698	6796	6894	6992	7089	7187	7285	9
4	7383	7481	7579	7676	7774	7872	7969	8067	8165	8262	
5	8360	8458	8555	8653	8750	8848	8945	9043	9140	9237	
6	9335	9432	9530	9627	9724	9821	9919	0016	0113	0210	
7	650308	0405	0502	0599	0696	0793	0890	0987	1084	1181	
8	1278	1375	1472	1569	1666	1762	1859	1956	2053	2150	9
9	2246	2343	2440	2536	2633	2730	2826	2923	3019	3116	
450	3213	3309	3405	3502	3598	3695	3791	3888	3984	4080	
1	4177	4273	4369	4465	4562	4658	4754	4850	4946	5042	
2	5138	5235	5331	5427	5523	5619	5715	5810	5906	6002	9
3	6098	6194	6290	6386	6482	6577	6673	6769	6864	6960	
4	7056	7152	7247	7343	7438	7534	7629	7725	7820	7916	
5	8011	8107	8202	8298	8393	8488	8584	8679	8774	8870	
6	8965	9060	9155	9250	9346	9441	9536	9631	9726	9821	
7	9916	0011	0106	0201	0296	0391	0486	0581	0676	0771	9
8	660865	0960	1055	1150	1245	1339	1434	1529	1623	1718	
9	1813	1907	2002	2096	2191	2286	2380	2475	2569	2663	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8
105	10.5	21.0	31.5	42.0	52.5	63.0	73.5	84.0
104	10.4	20.8	31.2	41.6	52.0	62.4	72.8	83.2
103	10.3	20.6	30.9	41.2	51.5	61.8	72.1	82.4
[illegible]	10.2	20.4	30.6	40.8	51.0	61.2	71.4	81.6
[illegible]	10.1	20.2	30.3	40.4	50.5	60.6	70.7	80.8
[illegible]	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0
[illegible]	.9	19.8	29.7	39.6	49.5	59.4	69.3	79.2

N	0	1	2	3	4	5	6	7	8	9	Diff.
460	662758	2852	2947	3041	3135	3230	3324	3418	3512	3607	
1	3701	3795	3889	3983	4078	4172	4266	4360	4454	4548	
2	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	94
3	5581	5675	5769	5862	5956	6050	6143	6237	6331	6424	
4	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	
5	7453	7546	7640	7733	7826	7920	8013	8106	8199	8293	
6	8386	8479	8572	8665	8759	8852	8945	9038	9131	9224	
7	9317	9410	9503	9596	9689	9782	9875	9967	0060	0153	93
8	670246	0339	0431	0524	0617	0710	0802	0895	0988	1080	
9	1173	1265	1358	1451	1543	1636	1728	1821	1913	2005	
470	2098	2190	2283	2375	2467	2560	2652	2744	2836	2929	
1	3021	3113	3205	3297	3390	3482	3574	3666	3758	3850	
2	3942	4034	4126	4218	4310	4402	4494	4586	4677	4769	92
3	4861	4953	5045	5137	5228	5320	5412	5503	5595	5687	
4	5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	
5	6694	6785	6876	6968	7059	7151	7242	7333	7424	7516	
6	7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	
7	8518	8609	8700	8791	8882	8973	9064	9155	9246	9337	91
8	9428	9519	9610	9700	9791	9882	9973	0063	0154	0245	
9	680336	0426	0517	0607	0698	0789	0879	0970	1060	1151	
480	1241	1332	1422	1513	1603	1693	1784	1874	1964	2055	
1	2145	2235	2326	2416	2506	2596	2686	2777	2867	2957	
2	3047	3137	3227	3317	3407	3497	3587	3677	3767	3857	90
3	3947	4037	4127	4217	4307	4396	4486	4576	4666	4756	
4	4845	4935	5025	5114	5204	5294	5383	5473	5563	5652	
5	5742	5831	5921	6010	6100	6189	6279	6368	6458	6547	
6	6636	6726	6815	6904	6994	7083	7172	7261	7351	7440	
7	7529	7618	7707	7796	7886	7975	8064	8153	8242	8331	89
8	8420	8509	8598	8687	8776	8865	8953	9042	9131	9220	
9	9309	9398	9486	9575	9664	9753	9841	9930	0019	0107	
490	690196	0285	0373	0462	0550	0639	0728	0816	0905	0993	
1	1081	1170	1258	1347	1435	1524	1612	1700	1789	1877	
2	1965	2053	2142	2230	2318	2406	2494	2583	2671	2759	
3	2847	2935	3023	3111	3199	3287	3375	3463	3551	3639	88
4	3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	
5	4605	4693	4781	4868	4956	5044	5131	5219	5307	5394	
6	5482	5569	5657	5744	5832	5919	6007	6094	6182	6269	
7	6356	6444	6531	6618	6706	6793	6880	6968	7055	7142	
8	7229	7317	7404	7491	7578	7665	7752	7839	7926	8014	
9	8100	8188	8275	8362	8449	8535	8622	8709	8796	8883	87

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
98	9.8	19.6	29.4	39.2	49.0	58.8	68.6	78.4	88.2
97	9.7	19.4	29.1	38.8	48.5	58.2	67.9	77.6	87.3
96	9.6	19.2	28.8	38.4	48.0	57.6	67.2	76.8	86.4
95	9.5	19.0	28.5	38.0	47.5	57.0	66.5	76.0	85.5
94	9.4	18.8	28.2	37.6	47.0	56.4	65.8	75.2	84.6
93	9.3	18.6	27.9	37.2	46.5	55.8	65.1	74.4	83.7
92	9.2	18.4	27.6	36.8	46.0	55.2	64.4	73.6	82.8
91	9.1	18.2	27.3	36.4	45.5	54.6	63.7	72.8	81.9
90	9.0	18.0	27.0	36.0	45.0	54.0	63.0	72.0	81.
89	8.9	17.8	26.7	35.6	44.5	53.4	62.3	71.2	80
88	8.8	17.6	26.4	35.2	44.0	52.8	61.6	70.4	7
87	8.7	17.4	26.1	34.8	43.5	52.2	60.9	69.6	
86	8.6	17.2	25.8	34.4	43.0	51.6	60.2	68.8	

N.	0	1	2	3	4	5	6	7	8	9	Diff.
500	698970	9057	9144	9231	9317	9404	9491	9578	9664	9751	
1	9838	9924	0011	0098	0184	0271	0358	0444	0531	0617	
2	700704	0790	0877	0963	1050	1136	1222	1309	1395	1482	
3	1568	1654	1741	1827	1913	1999	2086	2172	2258	2344	
4	2431	2517	2603	2689	2775	2861	2947	3033	3119	3205	
5	3291	3377	3463	3549	3635	3721	3807	3893	3979	4065	86
6	4151	4236	4322	4408	4494	4579	4665	4751	4837	4922	
7	5008	5094	5179	5265	5350	5436	5522	5607	5693	5778	
8	5864	5949	6035	6120	6206	6291	6376	6462	6547	6632	
9	6718	6803	6888	6974	7059	7144	7229	7315	7400	7485	
510	7570	7655	7740	7826	7911	7996	8081	8166	8251	8336	85
1	8421	8506	8591	8676	8761	8846	8931	9015	9100	9185	
2	9270	9355	9440	9524	9609	9694	9779	9863	9948	0033	
3	710117	0202	0287	0371	0456	0540	0625	0710	0794	0879	
4	0963	1048	1132	1217	1301	1385	1470	1554	1639	1723	
5	1807	1892	1976	2060	2144	2229	2313	2397	2481	2566	
6	2650	2734	2818	2902	2986	3070	3154	3238	3323	3407	
7	3491	3575	3659	3742	3826	3910	3994	4078	4162	4246	84
8	4330	4414	4497	4581	4665	4749	4833	4916	5000	5084	
9	5167	5251	5335	5418	5502	5586	5669	5753	5836	5920	
520	6003	6087	6170	6254	6337	6421	6504	6588	6671	6754	
1	6838	6921	7004	7088	7171	7254	7338	7421	7504	7587	
2	7671	7754	7837	7920	8003	8086	8169	8253	8336	8419	
3	8502	8585	8668	8751	8834	8917	9000	9083	9165	9248	83
4	9331	9414	9497	9580	9663	9745	9828	9911	9994	0077	
5	720159	0242	0325	0407	0490	0573	0655	0738	0821	0903	
6	0986	1068	1151	1233	1316	1398	1481	1563	1646	1728	
7	1811	1893	1975	2058	2140	2222	2305	2387	2469	2552	
8	2634	2716	2798	2881	2963	3045	3127	3209	3291	3374	
9	3456	3538	3620	3702	3784	3866	3948	4030	4112	4194	82
530	4276	4358	4440	4522	4604	4685	4767	4849	4931	5013	
1	5095	5176	5258	5340	5422	5503	5585	5667	5748	5830	
2	5912	5993	6075	6156	6238	6320	6401	6483	6564	6646	
3	6727	6809	6890	6972	7053	7134	7216	7297	7379	7460	
4	7541	7623	7704	7785	7866	7948	8029	8110	8191	8273	
5	8354	8435	8516	8597	8678	8759	8841	8922	9003	9084	
6	9165	9246	9327	9408	9489	9570	9651	9732	9813	9893	81
7	9974	0055	0136	0217	0298	0378	0459	0540	0621	0702	
8	730782	0863	0944	1024	1105	1186	1266	1347	1428	1508	
9	1589	1669	1750	1830	1911	1991	2072	2152	2233	2313	
540	2394	2474	2555	2635	2715	2796	2876	2956	3037	3117	
1	3197	3278	3358	3438	3518	3598	3679	3759	3839	3919	
2	3999	4079	4160	4240	4320	4400	4480	4560	4640	4720	
3	4800	4880	4960	5040	5120	5200	5279	5359	5439	5519	80
4	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
[illegible]	[illegible]	17.4	26.1	34.8	43.5	52.2	60.9	69.6	78.3
[illegible]	[illegible]	17.2	25.8	34.4	43.0	51.6	60.2	68.8	77.4
[illegible]	[illegible]	17.0	25.5	34.0	42.5	51.0	59.5	68.0	76.5
[illegible]	[illegible]	16.8	25.2	33.6	42.0	50.4	58.8	67.2	75.6

N.	0	1	2	3	4	5	6	7	8	9	Diff.
545	736397	6476	6556	6635	6715	6795	6874	6954	7034	7113	
6	7193	7272	7352	7431	7511	7590	7670	7749	7829	7908	
7	7987	8067	8146	8225	8305	8384	8463	8543	8622	8701	
8	8781	8860	8939	9018	9097	9177	9256	9335	9414	9493	
9	9572	9651	9731	9810	9889	9968	0047	0126	0205	0284	79
550	740363	0442	0521	0600	0678	0757	0836	0915	0994	1073	
1	1152	1230	1309	1388	1467	1546	1624	1703	1782	1860	
2	1939	2018	2096	2175	2254	2332	2411	2489	2568	2647	
3	2725	2804	2882	2961	3039	3118	3196	3275	3353	3431	
4	3510	3588	3667	3745	3823	3902	3980	4058	4136	4215	
5	4293	4371	4449	4528	4606	4684	4762	4840	4919	4997	
6	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
7	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	
8	6634	6712	6790	6868	6945	7023	7101	7179	7256	7334	
9	7412	7489	7567	7645	7722	7800	7878	7955	8033	8110	
560	8188	8266	8343	8421	8498	8576	8653	8731	8808	8885	
1	8963	9040	9118	9195	9272	9350	9427	9504	9582	9659	
2	9736	9814	9891	9968	0045	0123	0200	0277	0354	0431	
3	750508	0586	0663	0740	0817	0894	0971	1048	1125	1202	
4	1279	1356	1433	1510	1587	1664	1741	1818	1895	1972	
5	2048	2125	2202	2279	2356	2433	2509	2586	2663	2740	77
6	2816	2893	2970	3047	3123	3200	3277	3353	3430	3506	
7	3583	3660	3736	3813	3889	3966	4042	4119	4195	4272	
8	4348	4425	4501	4578	4654	4730	4807	4883	4960	5036	
9	5112	5189	5265	5341	5417	5494	5570	5646	5722	5799	
570	5875	5951	6027	6103	6180	6256	6332	6408	6484	6560	
1	6636	6712	6788	6864	6940	7016	7092	7168	7244	7320	76
2	7396	7472	7548	7624	7700	7775	7851	7927	8003	8079	
3	8155	8230	8306	8382	8458	8533	8609	8685	8761	8836	
4	8912	8988	9063	9139	9214	9290	9366	9441	9517	9592	
5	9668	9743	9819	9894	9970	0045	0121	0196	0272	0347	
6	760422	0498	0573	0649	0724	0799	0875	0950	1025	1101	
7	1176	1251	1326	1402	1477	1552	1627	1702	1778	1853	
8	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604	75
9	2679	2754	2829	2904	2978	3053	3128	3203	3278	3353	
580	3428	3503	3578	3653	3727	3802	3877	3952	4027	4101	
1	4176	4251	4326	4400	4475	4550	4624	4699	4774	4848	
2	4923	4998	5072	5147	5221	5296	5870	5445	5520	5594	
3	5669	5743	5818	5892	5966	6041	6115	6190	6264	6338	
4	6413	6487	6562	6636	6710	6785	6859	6933	7007	7082	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
83	8.3	16.6	24.9	33.2	41.5	49.8	58.1	66.4	74.7
82	8.2	16.4	24.6	32.8	41.0	49.2	57.4	65.6	73.8
81	8.1	16.2	24.3	32.4	40.5	48.6	56.7	64.8	72.9
80	8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0
79	7.9	15.8	23.7	31.6	39.5	47.4	55.3	63.2	71.1
78	7.8	15.6	23.4	31.2	39.0	46.8	54.6	62.4	70.2
77	7.7	15.4	23.1	30.8	38.5	46.2	53.9	61.6	69.3
76	7.6	15.2	22.8	30.4	38.0	45.6	53.2	60.8	68.4
75	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	[illegible]
74	7.4	14.8	22.2	29.6	37.0	44.4	51.8	59.2	

N.	0	1	2	3	4	5	6	7	8	9	Diff.
585	767156	7230	7304	7379	7453	7527	7601	7675	7749	7823	
6	7898	7972	8046	8120	8194	8268	8342	8416	8490	8564	74
7	8638	8712	8786	8860	8934	9008	9082	9156	9230	9303	
8	9377	9451	9525	9599	9673	9746	9820	9894	9968	0042	
9	770115	0189	0263	0336	0410	0484	0557	0631	0705	0778	
590	0852	0926	0999	1073	1146	1220	1293	1367	1440	1514	
1	1587	1661	1734	1808	1881	1955	2028	2102	2175	2248	
2	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981	
3	3055	3128	3201	3274	3348	3421	3494	3567	3640	3713	
4	3786	[illegible]	3933	4006	4079	4152	4225	4298	4371	4444	73
5	4517	4590	4663	4736	4809	4882	4955	5028	5100	5173	
6	5246	5319	5392	5465	5538	5610	5683	5756	5829	5902	
7	5974	6047	6120	6193	6265	6338	6411	6483	6556	6629	
8	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354	
9	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079	
600	8151	8224	8296	8368	8441	8513	8585	8658	8730	8802	
1	8874	8947	9019	9091	9163	9236	9308	9380	9452	9524	
2	9596	9669	9741	9813	9885	9957	0029	0101	0173	0245	
3	780317	0389	0461	0533	0605	0677	0749	0821	0893	0965	72
4	1037	1109	1181	1253	1324	1396	1468	1540	1612	1684	
5	1755	1827	1899	1971	2042	2114	2186	2258	2329	2401	
6	2473	2544	2616	2688	2759	2831	2902	2974	3046	3117	
7	3189	3260	3332	3403	3475	3546	3618	3689	3761	3832	
8	3904	3975	4046	4118	4189	4261	4332	4403	4475	4546	
9	4617	4689	4760	4831	4902	4974	5045	5116	5187	5259	
610	5330	5401	5472	5543	5615	5686	5757	5828	5899	5970	
1	6041	6112	6183	6254	6325	6396	6467	6538	6609	6680	71
2	6751	6822	6893	6964	7035	7106	7177	7248	7319	7390	
3	7460	7531	7602	7673	7744	7815	7885	7956	8027	8098	
4	8168	8239	8310	8381	8451	8522	8593	8663	8734	8804	
5	8875	8946	9016	9087	9157	9228	9299	9369	9440	9510	
6	9581	9651	9722	9792	9863	9933	0004	0074	0144	0215	
7	790285	0356	0426	0496	0567	0637	0707	0778	0848	0918	
8	0988	1059	1129	1199	1269	1340	1410	1480	1550	1620	
9	1691	1761	1831	1901	1971	2041	2111	2181	2252	2322	
620	2392	2462	2532	2602	2072	2742	2812	2882	2952	3022	70
1	3092	3162	3231	3301	3371	3441	3511	3581	3651	3721	
2	3790	3860	3930	4000	4070	4139	4209	4279	4349	4418	
3	4488	4558	4627	4697	4767	4836	4906	4976	5045	5115	
4	5185	5254	5324	5393	5463	5532	5602	5672	5741	5811	
5	5880	5949	6019	6088	6158	6227	6297	6366	6436	6505	
6	6574	6644	6713	6782	6852	6921	6990	7060	7129	7198	
7	7268	7337	7406	7475	7545	7614	7683	7752	7821	7890	
8	7960	8029	8098	8167	8236	8305	8374	8443	8513	8582	
9	8651	8720	8789	8858	8927	8996	9065	9134	9203	9272	69

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
75	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5
[illegible]	*7.4*	*14.8*	22.2	29.6	37.0	44.4	51.8	59.2	66.6
[illegible]	*7.3*	*14.6*	21.9	29.2	36.5	43.8	51.1	58.4	65.7
[illegible]	*7.2*	*14.4*	21.6	28.8	36.0	43.2	50.4	57.6	64.8
[illegible]	*7.1*	*14.2*	21.3	28.4	35.5	42.6	49.7	56.8	63.9
[illegible]	*7.0*	*14.0*	21.0	28.0	35.0	42.0	49.0	56.0	63.0
[illegible]	[illegible]	*13.8*	20.7	27.6	34.5	41.4	48.3	55.2	[illegible]

0	1	2	3	4	5	6	7	8	9	Diff.
799341	9409	9478	9547	9616	9685	9754	9823	9892	9961	
800029	0098	0167	0236	0305	0373	0442	0511	0580	0648	
0717	0786	0854	0923	0992	1061	1129	1198	1266	1335	
1404	1472	1541	1609	1678	1747	1815	1884	1952	2021	
2089	2158	2226	2295	2363	2432	2500	2568	2637	2705	
2774	2842	2910	2979	3047	3116	3184	3252	3321	3389	
3457	3525	3594	3662	3730	3798	3867	3935	4003	4071	
4139	4208	4276	4344	4412	4480	4548	4616	4685	4753	
4821	4889	4957	5025	5093	5161	5229	5297	5365	5433	68
5501	5569	5637	5705	5773	5841	5908	5976	6044	6112	
806180	6248	6316	6384	6451	6519	6587	6655	6723	6790	
6858	6926	6994	7061	7129	7197	7264	7332	7400	7467	
7535	7603	7670	7738	7806	7873	7941	8008	8076	8143	
8211	8279	8346	8414	8481	8549	8616	8684	8751	8818	
8886	8953	9021	9088	9156	9223	9290	9358	9425	9492	
9560	9627	9694	9762	9829	9896	9964	0031	0098	0165	
810233	0300	0367	0434	0501	0569	0636	0703	0770	0837	
0904	0971	1039	1106	1173	1240	1307	1374	1441	1508	67
1575	1642	1709	1776	1843	1910	1977	2044	2111	2178	
2245	2312	2379	2445	2512	2579	2646	2713	2780	2847	
2913	2980	3047	3114	3181	3247	3314	3381	3448	3514	
3581	3648	3714	3781	3848	3914	3981	4048	4114	4181	
4248	4314	4381	4447	4514	4581	4647	4714	4780	4847	
4913	4980	5046	5113	5179	5246	5312	5378	5445	5511	
5578	5644	5711	5777	5843	5910	5976	6042	6109	6175	
6241	6308	6374	6440	6506	6573	6639	6705	6771	6838	
6904	6970	7036	7102	7169	7235	7301	7367	7433	7499	
7565	7631	7698	7764	7830	7896	7962	8028	8094	8160	
8226	8292	8358	8424	8490	8556	8622	8688	8754	8820	66
8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	
9544	9610	9676	9741	9807	9873	9939	0004	0070	0136	
820201	0267	0333	0399	0464	0530	0595	0661	0727	0792	
0858	0924	0989	1055	1120	1186	1251	1317	1382	1448	
1514	1579	1645	1710	1775	1841	1906	1972	2037	2103	
2168	2233	2299	2364	2430	2495	2560	2626	2691	2756	
2822	2887	2952	3018	3083	3148	3213	3279	3344	3409	
3474	3539	3605	3670	3735	3800	3865	3930	3996	4061	
4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	65
4776	4841	4906	4971	5036	5101	5166	5231	5296	5361	
5426	5491	5556	5621	5686	5751	5815	5880	5945	6010	
6075	6140	6204	6269	6334	6399	6464	6528	6593	6658	
6723	6787	6852	6917	6981	7046	7111	7175	7240	7305	
7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	
8015	8080	8144	8209	8273	8338	8402	8467	8531	8595	
8660	8724	8789	8853	8918	8982	9046	9111	9175	9239	

PROPORTIONAL PARTS.

f.	1	2	3	4	5	6	7	8	9
	6.8	13.6	20.4	27.2	34.0	40.8	47.6	54.4	61.
	6.7	13.4	20.1	26.8	33.5	40.2	46.9	53.6	60.
	6.6	13.2	19.8	26.4	33.0	39.6	46.2	52.8	59
	6.5	13.0	19.5	26.0	32.5	39.0	45.5	52.0	5
	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	

N.	0	1	2	3	4	5	6	7	8	9	Diff.
675	829304	9368	9432	9497	9561	9625	9690	9754	9818	9882	
6	9947	0011	0075	0139	0204	0268	0332	0396	0460	0525	
7	830589	0653	0717	0781	0845	0909	0973	1037	1102	1166	
8	1230	1294	1358	1422	1486	1550	1614	1678	1742	1806	64
9	1870	1934	1998	2062	2126	2189	2253	2317	2381	2445	
680	2509	2573	2637	2700	2764	2828	2892	2956	3020	3083	
1	3147	3211	3275	3338	3402	3466	3530	3593	3657	3721	
2	3784	3848	3912	3975	4039	4103	4166	4230	4294	4357	
3	4421	4484	4548	4611	4675	4739	4802	4866	4929	4993	
4	5056	5120	5183	5247	5310	5373	5437	5500	5564	5627	
5	5691	5754	5817	5881	5944	6007	6071	6134	6197	6261	
6	6324	6387	6451	6514	6577	6641	6704	6767	6830	6894	
7	6957	7020	7083	7146	7210	7273	7336	7399	7462	7525	
8	7588	7652	7715	7778	7841	7904	7967	8030	8093	8156	
9	8219	8282	8345	8408	8471	8534	8597	8660	8723	8786	63
690	8849	8912	8975	9038	9101	9164	9227	9289	9352	9415	
1	9478	9541	9604	9667	9729	9792	9855	9918	9981	0043	
2	840106	0169	0232	0294	0357	0420	0482	0545	0608	0671	
3	0733	0796	0859	0921	0984	1046	1109	1172	1234	1297	
4	1359	1422	1485	1547	1610	1672	1735	1797	1860	1922	
5	1985	2047	2110	2172	2235	2297	2360	2422	2484	2547	
6	2609	2672	2734	2796	2859	2921	2983	3046	3108	3170	
7	3233	3295	3357	3420	3482	3544	3606	3669	3731	3793	
8	3855	3918	3980	4042	4104	4166	4229	4291	4353	4415	
9	4477	4539	4601	4664	4726	4788	4850	4912	4974	5036	
700	5098	5160	5222	5284	5346	5408	5470	5532	5594	5656	62
1	5718	5780	5842	5904	5966	6028	6090	6151	6213	6275	
2	6337	6399	6461	6523	6585	6646	6708	6770	6832	6894	
3	6955	7017	7079	7141	7202	7264	7326	7388	7449	7511	
4	7573	7634	7696	7758	7819	7881	7943	8004	8066	8128	
5	8189	8251	8312	8374	8435	8497	8559	8620	8682	8743	
6	8805	8866	8928	8989	9051	9112	9174	9235	9297	9358	
7	9419	9481	9542	9604	9665	9726	9788	9849	9911	9972	
8	850033	0095	0156	0217	0279	0340	0401	0462	0524	0585	
9	0646	0707	0769	0830	0891	0952	1014	1075	1136	1197	
710	1258	1320	1381	1442	1503	1564	1625	1686	1747	1809	
1	1870	1931	1992	2053	2114	2175	2236	2297	2358	2419	61
2	2480	2541	2602	2663	2724	2785	2846	2907	2968	3029	
3	3090	3150	3211	3272	3333	3394	3455	3516	3577	3637	
4	3698	3759	3820	3881	3941	4002	4063	4124	4185	4245	
5	4306	4367	4428	4488	4549	4610	4670	4731	4792	4852	
6	4913	4974	5034	5095	5156	5216	5277	5337	5398	5459	
7	5519	5580	5640	5701	5761	5822	5882	5943	6003	6064	
8	6124	6185	6245	6306	6366	6427	6487	6548	6608	6668	
9	6729	6789	6850	6910	6970	7031	7091	7152	7212	7272	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
65	6.5	13.0	19.5	26.0	32.5	39.0	45.5	52.0	58.5
64	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6
63	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7
62	6.2	12.4	18.6	24.8	31.0	37.2	43.4	49.6	55.
61	6.1	12.2	18.3	24.4	30.5	36.6	42.7	48.8	54
[illegible]	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	5

N.	0	1	2	3	4	5	6	7	8	9	Diff.
720	857332	7393	7453	7513	7574	7634	7694	7755	7815	7875	
1	7935	7995	8056	8116	8176	8236	8297	8357	8417	8477	
2	8537	8597	8657	8718	8778	8838	8898	8958	9018	9078	
3	9138	9198	9258	9318	9379	9439	9499	9559	9619	9679	60
4	9739	9799	9859	9918	9978	0038	0098	0158	0218	0278	
5	860338	0398	0458	0518	0578	0637	0697	0757	0817	0877	
6	0937	0996	1056	1116	1176	1236	1295	1355	1415	1475	
7	1534	1594	1654	1714	1773	1833	1893	1952	2012	2072	
8	2131	2191	2251	2310	2370	2430	2489	2549	2608	2668	
9	2728	2787	2847	2906	2966	3025	3085	3144	3204	3263	
730	3323	3382	3442	3501	3561	3620	3680	3739	3799	3858	
1	3917	3977	4036	4096	4155	4214	4274	4333	4392	4452	
2	4511	4570	4630	4689	4748	4808	4867	4926	4985	5045	
3	5104	5163	5222	5282	5341	5400	5459	5519	5578	5637	
4	5696	5755	5814	5874	5933	5992	6051	6110	6169	6228	
5	6287	6346	6405	6465	6524	6583	6642	6701	6760	6819	
6	6878	6937	6996	7055	7114	7173	7232	7291	7350	7409	59
7	7467	7526	7585	7644	7703	7762	7821	7880	7939	7998	
8	8056	8115	8174	8233	8292	8350	8409	8468	8527	8586	
9	8644	8703	8762	8821	8879	8938	8997	9056	9114	9173	
740	9232	9290	9349	9408	9466	9525	9584	9642	9701	9760	
1	9818	9877	9935	9994	0053	0111	0170	0228	0287	0345	
2	870404	0462	0521	0579	0638	0696	0755	0813	0872	0930	
3	0989	1047	1106	1164	1223	1281	1339	1398	1456	1515	
4	1573	1631	1690	1748	1806	1865	1923	1981	2040	2098	
5	2156	2215	2273	2331	2389	2448	2506	2564	2622	2681	
6	2739	2797	2855	2913	2972	3030	3088	3146	3204	3262	
7	3321	3379	3437	3495	3553	3611	3669	3727	3785	3844	
8	3902	3960	4018	4076	4134	4192	4250	4308	4366	4424	58
9	4482	4540	4598	4656	4714	4772	4830	4888	4945	5003	
750	5061	5119	5177	5235	5293	5351	5409	5466	5524	5582	
1	5640	5698	5756	5813	5871	5929	5987	6045	6102	6160	
2	6218	6276	6333	6391	6449	6507	6564	6622	6680	6737	
3	6795	6853	6910	6968	7026	7083	7141	7199	7256	7314	
4	7371	7429	7487	7544	7602	7659	7717	7774	7832	7889	
5	7947	8004	8062	8119	8177	8234	8292	8349	8407	8464	
6	8522	8579	8637	8694	8752	8809	8866	8924	8981	9039	
7	9096	9153	9211	9268	9325	9383	9440	9497	9555	9612	
8	9669	9726	9784	9841	9898	9956	0013	0070	0127	0185	
9	880242	0299	0356	0413	0471	0528	0585	0642	0699	0756	
760	0814	0871	0928	0985	1042	1099	1156	1213	1271	1328	
1	1385	1442	1499	1556	1613	1670	1727	1784	1841	1898	
2	1955	2012	2069	2126	2183	2240	2297	2354	2411	2468	57
3	2525	2581	2638	2695	2752	2809	2866	2923	2980	3037	
4	3093	3150	3207	3264	3321	3377	3434	3491	3548	3605	

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
59	*5.9*	*11.8*	*17.7*	23.6	29.5	35.4	41.3	47.2	
58	*5.8*	*11.6*	*17.4*	23.2	29.0	34.8	40.6	46.4	
57	*5.7*	*11.4*	*17.1*	22.8	28.5	34.2	39.9	45.6	
56	*5.6*	*11.2*	*16.8*	22.4	28.0	33.6	39.2	44.8	

N.	0	1	2	3	4	5	6	7	8	9	Diff.
765	883661	3718	3775	3832	3888	3945	4002	4059	4115	4172	
6	4229	4285	4342	4399	4455	4512	4569	4625	4682	4739	
7	4795	4852	4909	4965	5022	5078	5135	5192	5248	5305	
8	5361	5418	5474	5531	5587	5644	5700	5757	5813	5870	
9	5926	5983	6039	6096	6152	6209	6265	6321	6378	6434	
770	6491	6547	6604	6660	6716	6773	6829	6885	6942	6998	
1	7054	7111	7167	7223	7280	7336	7392	7449	7505	7561	
2	7617	7674	7730	7786	7842	7898	7955	8011	8067	8123	
3	8179	8236	8292	8348	8404	8460	8516	8573	8629	8685	
4	8741	8797	8853	8909	8965	9021	9077	9134	9190	9246	
5	9302	9358	9414	9470	9526	9582	9638	9694	9750	9806	56
6	9862	9918	9974	0030	0086	0141	0197	0253	0309	0365	
7	890421	0477	0533	0589	0645	0700	0756	0812	0868	0924	
8	0980	1035	1091	1147	1203	1259	1314	1370	1426	1482	
9	1537	1593	1649	1705	1760	1816	1872	1928	1983	2039	
780	2095	2150	2206	2262	2317	2373	2429	2484	2540	2595	
1	2651	2707	2762	2818	2873	2929	2985	3040	3096	3151	
2	3207	3262	3318	3373	3429	3484	3540	3595	3651	3706	
3	3762	3817	3873	3928	3984	4039	4094	4150	4205	4261	
4	4316	4371	4427	4482	4538	4593	4648	4704	4759	4814	
5	4870	4925	4980	5036	5091	5146	5201	5257	5312	5367	
6	5423	5478	5533	5588	5644	5699	5754	5809	5864	5920	
7	5975	6030	6085	6140	6195	6251	6306	6361	6416	6471	
8	6526	6581	6636	6692	6747	6802	6857	6912	6967	7022	
9	7077	7132	7187	7242	7297	7352	7407	7462	7517	7572	55
790	7627	7682	7737	7792	7847	7902	7957	8012	8067	8122	
1	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	
2	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	
3	9273	9328	9383	9437	9492	9547	9602	9656	9711	9766	
4	9821	9875	9930	9985	0039	0094	0149	0203	0258	0312	
5	900367	0422	0476	0531	0586	0640	0695	0749	0804	0859	
6	0913	0968	1022	1077	1131	1186	1240	1295	1349	1404	
7	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	
8	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	
9	2547	2601	2655	2710	2764	2818	2873	2927	2981	3036	
800	3090	3144	3199	3253	3307	3361	3416	3470	3524	3578	
1	3633	3687	3741	3795	3849	3904	3958	4012	4066	4120	
2	4174	4229	4283	4337	4391	4445	4499	4553	4607	4661	
3	4716	4770	4824	4878	4932	4986	5040	5094	5148	5202	
4	5256	5310	5364	5418	5472	5526	5580	5634	5688	5742	54
5	5796	5850	5904	5958	6012	6066	6119	6173	6227	6281	
6	6335	6389	6443	6497	6551	6604	6658	6712	6766	6820	
7	6874	6927	6981	7035	7089	7143	7196	7250	7304	7358	
8	7411	7465	7519	7573	7626	7680	7734	7787	7841	7895	
9	7949	8002	8056	8110	8163	8217	8270	8324	8378	8431	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
57	5.7	11.4	17.1	22.8	28.5	34.2	39.9	45.6	51.3
56	5.6	11.2	16.8	22.4	28.0	33.6	39.2	44.8	50.4
55	5.5	11.0	16.5	22.0	27.5	33.0	38.5	44.0	49.5
[illegible]	5.4	10.8	16.2	21.6	27.0	32.4	37.8	43.2	48.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
810	908485	8539	8592	8646	8699	8753	8807	8860	8914	8967	
1	9021	9074	9128	9181	9235	9289	9342	9396	9449	9503	
2	9556	9610	9663	9716	9770	9823	9877	9930	9984	0037	
3	910091	0144	0197	0251	0304	0358	0411	0464	0518	0571	
4	0624	0678	0731	0784	0838	0891	0944	0998	1051	1104	
5	1158	1211	1264	1317	1371	1424	1477	1530	1584	1637	
6	1690	1743	1797	1850	1903	1956	2009	2063	2116	2169	
7	2222	2275	2328	2381	2435	2488	2541	2594	2647	2700	
8	2753	2806	2859	2913	2966	3019	3072	3125	3178	3231	
9	3284	3337	3390	3443	3496	3549	3602	3655	3708	3761	53
820	3814	3867	3920	3973	4026	4079	4132	4184	4237	4290	
1	4343	4396	4449	4502	4555	4608	4660	4713	4766	4819	
2	4872	4925	4977	5030	5083	5136	5189	5241	5294	5347	
3	5400	5453	5505	5558	5611	5664	5716	5769	5822	5875	
4	5927	5980	6033	6085	6138	6191	6243	6296	6349	6401	
5	6454	6507	6559	6612	6664	6717	6770	6822	6875	6927	
6	6980	7033	7085	7138	7190	7243	7295	7348	7400	7453	
7	7506	7558	7611	7663	7716	7768	7820	7873	7925	7978	
8	8030	8083	8135	8188	8240	8293	8345	8397	8450	8502	
9	8555	8607	8659	8712	8764	8816	8869	8921	8973	9026	
830	9078	9130	9183	9235	9287	9340	9392	9444	9496	9549	
1	9601	9653	9706	9758	9810	9862	9914	9967	0019	0071	
2	920123	0176	0228	0280	0332	0384	0436	0489	0541	0593	
3	0645	0697	0749	0801	0853	0906	0958	1010	1062	1114	
4	1166	1218	1270	1322	1374	1426	1478	1530	1582	1634	52
5	1686	1738	1790	1842	1894	1946	1998	2050	2102	2154	
6	2206	2258	2310	2362	2414	2466	2518	2570	2622	2674	
7	2725	2777	2829	2881	2933	2985	3037	3089	3140	3192	
8	3244	3296	3348	3399	3451	3503	3555	3607	3658	3710	
9	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	
840	4279	4331	4383	4434	4486	4538	4589	4641	4693	4744	
1	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	
2	5312	5364	5415	5467	5518	5570	5621	5673	5725	5776	
3	5828	5879	5931	5982	6034	6085	6137	6188	6240	6291	
4	6342	6394	6445	6497	6548	6600	6651	6702	6754	6805	
5	6857	6908	6959	7011	7062	7114	7165	7216	7268	7319	
6	7370	7422	7473	7524	7576	7627	7678	7730	7781	7832	
7	7883	7935	7986	8037	8088	8140	8191	8242	8293	8345	
8	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	
9	8908	8959	9010	9061	9112	9163	9215	9266	9317	9368	
850	9419	9470	9521	9572	9623	9674	9725	9776	9827	9879	51
1	9930	9981	0032	0083	0134	0185	0236	0287	0338	0389	
2	930440	0491	0542	0592	0643	0694	0745	0796	0847	0898	
3	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	
4	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
53	5.3	10.6	15.9	21.2	26.5	31.8	37.1	42.4	4
52	5.2	10.4	15.6	20.8	26.0	31.2	36.4	41.6	
51	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	
50	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40	

N.	0	1	2	3	4	5	6	7	8	9	Diff.
855	931966	2017	2068	2118	2169	2220	2271	2322	2372	2423	
6	2474	2524	2575	2626	2677	2727	2778	2829	2879	2930	
7	2981	3031	3082	3133	3183	3234	3285	3335	3386	3437	
8	3487	3538	3589	3639	3690	3740	3791	3841	3892	3943	
9	3993	4044	4094	4145	4195	4246	4296	4347	4397	4448	
860	4498	4549	4599	4650	4700	4751	4801	4852	4902	4953	
1	5003	5054	5104	5154	5205	5255	5306	5356	5406	5457	
2	5507	5558	5608	5658	5709	5759	5809	5860	5910	5960	
3	6011	6061	6111	6162	6212	6262	6313	6363	6413	6463	
4	6514	6564	6614	6665	6715	6765	6815	6865	6916	6966	
5	7016	7066	7116	7167	7217	7267	7317	7367	7418	7468	
6	7518	7568	7618	7668	7718	7769	7819	7869	7919	7969	
7	8019	8069	8119	8169	8219	8269	8320	8370	8420	8470	50
8	8520	8570	8620	8670	8720	8770	8820	8870	8920	8970	
9	9020	9070	9120	9170	9220	9270	9320	9369	9419	9469	
870	9519	9569	9619	9669	9719	9769	9819	9869	9918	9968	
1	940018	0068	0118	0168	0218	0267	0317	0367	0417	0467	
2	0516	0566	0616	0666	0716	0765	0815	0865	0915	0964	
3	1014	1064	1114	1163	1213	1263	1313	1362	1412	1462	
4	1511	1561	1611	1660	1710	1760	1809	1859	1909	1958	
5	2008	2058	2107	2157	2207	2256	2306	2355	2405	2455	
6	2504	2554	2603	2653	2702	2752	2801	2851	2901	2950	
7	3000	3049	3099	3148	3198	3247	3297	3346	3396	3445	
8	3495	3544	3593	3643	3692	3742	3791	3841	3890	3939	
9	3989	4038	4088	4137	4186	4236	4285	4335	4384	4433	
880	4483	4532	4581	4631	4680	4729	4779	4828	4877	4927	
1	4976	5025	5074	5124	5173	5222	5272	5321	5370	5419	
2	5469	5518	5567	5616	5665	5715	5764	5813	5862	5912	
3	5961	6010	6059	6108	6157	6207	6256	6305	6354	6403	
4	6452	6501	6551	6600	6649	6698	6747	6796	6845	6894	
5	6943	6992	7041	7090	7140	7189	7238	7287	7336	7385	49
6	7434	7483	7532	7581	7630	7679	7728	7777	7826	7875	
7	7924	7973	8022	8070	8119	8168	8217	8266	8315	8364	
8	8413	8462	8511	8560	8608	8657	8706	8755	8804	8853	
9	8902	8951	8999	9048	9097	9146	9195	9244	9292	9341	
890	9390	9439	9488	9536	9585	9634	9683	9731	9780	9829	
1	9878	9926	9975	0024	0073	0121	0170	0219	0267	0316	
2	950365	0414	0462	0511	0560	0608	0657	0706	0754	0803	
3	0851	0900	0949	0997	1046	1095	1143	1192	1240	1289	
4	1338	1386	1435	1483	1532	1580	1629	1677	1726	1775	
5	1823	1872	1920	1969	2017	2066	2114	2163	2211	2260	
6	2308	2356	2405	2453	2502	2550	2599	2647	2696	2744	
7	2792	2841	2889	2938	2986	3034	3083	3131	3180	3228	
8	3276	3325	3373	3421	3470	3518	3566	3615	3663	3711	
9	3760	3808	3856	3905	3953	4001	4049	4098	4146	4194	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
[illegible]	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	45.9
[illegible]	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0
[illegible]	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.
[illegible]	.8	9.6	14.4	19.2	24.0	28.8	33.6	38.4	43.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
900	954243	4291	4339	4387	4435	4484	4532	4580	4628	4677	
1	4725	4773	4821	4869	4918	4966	5014	5062	5110	5158	
2	5207	5255	5303	5351	5399	5447	5495	5543	5592	5640	
3	5688	5736	5784	5832	5880	5928	5976	6024	6072	6120	
4	6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	
5	6649	6697	6745	6793	6840	6888	6936	6984	7032	7080	48
6	7128	7176	7224	7272	7320	7368	7416	7464	7512	7559	
7	7607	7655	7703	7751	7799	7847	7894	7942	7990	8038	
8	8086	8134	8181	8229	8277	8325	8373	8421	8468	8516	
9	8564	8612	8659	8707	8755	8803	8850	8898	8946	8994	
910	9041	9089	9137	9185	9232	9280	9328	9375	9423	9471	
1	9518	9566	9614	9661	9709	9757	9804	9852	9900	9947	
2	9995	0042	0090	0138	0185	0233	0280	0328	0376	0423	
3	960471	0518	0566	0613	0661	0709	0756	0804	0851	0899	
4	0946	0994	1041	1089	1136	1184	1231	1279	1326	1374	
5	1421	1469	1516	1563	1611	1658	1706	1753	1801	1848	
6	1895	1943	1990	2038	2085	2132	2180	2227	2275	2322	
7	2369	2417	2464	2511	2559	2606	2653	2701	2748	2795	
8	2843	2890	2937	2985	3032	3079	3126	3174	3221	3268	
9	3316	3363	3410	3457	3504	3552	3599	3646	3693	3741	
920	3788	3835	3882	3929	3977	4024	4071	4118	4165	4212	
1	4260	4307	4354	4401	4448	4495	4542	4590	4637	4684	
2	4731	4778	4825	4872	4919	4966	5013	5061	5108	5155	
3	5202	5249	5296	5343	5390	5437	5484	5531	5578	5625	
4	5672	5719	5766	5813	5860	5907	5954	6001	6048	6095	47
5	6142	6189	6236	6283	6329	6376	6423	6470	6517	6564	
6	6611	6658	6705	6752	6799	6845	6892	6939	6986	7033	
7	7080	7127	7173	7220	7267	7314	7361	7408	7454	7501	
8	7548	7595	7642	7688	7735	7782	7829	7875	7922	7969	
9	8016	8062	8109	8156	8203	8249	8296	8343	8390	8436	
930	8483	8530	8576	8623	8670	8716	8763	8810	8856	8903	
1	8950	8996	9043	9090	9136	9183	9229	9276	9323	9369	
2	9416	9463	9509	9556	9602	9649	9695	9742	9789	9835	
3	9882	9928	9975	0021	0068	0114	0161	0207	0254	0300	
4	970347	0393	0440	0486	0533	0579	0626	0672	0719	0765	
5	0812	0858	0904	0951	0997	1044	1090	1137	1183	1229	
6	1276	1322	1369	1415	1461	1508	1554	1601	1647	1693	
7	1740	1786	1832	1879	1925	1971	2018	2064	2110	2157	
8	2203	2249	2295	2342	2388	2434	2481	2527	2573	2619	
9	2666	2712	2758	2804	2851	2897	2943	2989	3035	3082	
940	3128	3174	3220	3266	3313	3359	3405	3451	3497	3543	
1	3590	3636	3682	3728	3774	3820	3866	3913	3959	4005	
2	4051	4097	4143	4189	4235	4281	4327	4374	4420	4466	
3	4512	4558	4604	4650	4696	4742	4788	4834	4880	4926	
4	4972	5018	5064	5110	5156	5202	5248	5294	5340	5386	46

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
47	*4.7*	*9.4*	14.1	18.8	23.5	28.2	32.9	37.6	
46	*4.6*	*9.2*	13.8	18.4	23.0	27.6	32.2	36.8	

N.	0	1	2	3	4	5	6	7	8	9	Diff.
945	975432	5478	5524	5570	5616	5662	5707	5753	5799	5845	
6	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	
7	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	
8	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	
9	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	
950	7724	7769	7815	7861	7906	7952	7998	8043	8089	8135	
1	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	
2	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	
3	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	
4	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	
5	980003	0049	0094	0140	0185	0231	0276	0322	0367	0412	
6	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	
7	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	
8	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	
9	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	
960	2271	2316	2362	2407	2452	2497	2543	2588	2633	2678	
1	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	
2	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	
3	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	
4	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	
5	4527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
6	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	
7	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	
8	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	
9	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	
970	6772	6817	6861	6906	6951	6996	7040	7085	7130	7175	
1	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	
2	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	
3	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	
4	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	
5	9005	9049	9094	9138	9183	9227	9272	9316	9361	9405	
6	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	
7	9895	9939	9983	0028	0072	0117	0161	0206	0250	0294	
8	990339	0383	0428	0472	0516	0561	0605	0650	0694	0738	
9	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	
980	1226	1270	1315	1359	1403	1448	1492	1536	1580	1625	
1	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	
2	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	
3	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	
4	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	
5	3436	3480	3524	3568	3613	3657	3701	3745	3789	3833	
6	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	
7	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
8	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	
9	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
46	*4.6*	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41.4
45	*4.5*	*9.0*	*13.5*	18.0	22.5	27.0	31.5	36.0	40.5
44	*4.4*	*8.8*	*13.2*	17.6	22.0	26.4	30.8	35.2	39.6
43	*4.3*	*8.6*	*12.9*	17.2	21.5	25.8	30.1	34.4	38.7

N.	0	1	2	3	4	5	6	7	8	9	Diff.
990	995635	5679	5723	5767	5811	5854	5898	5942	5986	6030	
1	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
2	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	
3	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	
4	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	
5	7823	7867	7910	7954	7998	8041	8085	8129	8172	8216	
6	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	
7	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	
8	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	
9	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43

LOGARITHMS OF NUMBERS FROM 1 TO 100.

N.	Log.	N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0.000000	21	1.322219	41	1.612784	61	1.785330	81	1.908485
2	0.301030	22	1.342423	42	1.623249	62	1.792392	82	1.913814
3	0.477121	23	1.361728	43	1.633468	63	1.799341	83	1.919078
4	0.602060	24	1.380211	44	1.643453	64	1.806180	84	1.924279
5	0.698970	25	1.397940	45	1.653213	65	1.812913	85	1.929419
6	0.778151	26	1.414973	46	1.662758	66	1.819544	86	1.934498
7	0.845098	27	1.431364	47	1.672098	67	1.826075	87	1.939519
8	0.903090	28	1.447158	48	1.681241	68	1.832509	88	1.944483
9	0.954243	29	1.462398	49	1.690196	69	1.838849	89	1.949390
10	1.000000	30	1.477121	50	1.698970	70	1.845098	90	1.954243
11	1.041393	31	1.491362	51	1.707570	71	1.851258	91	1.959041
12	1.079181	32	1.505150	52	1.716003	72	1.857332	92	1.963788
13	1.113943	33	1.518514	53	1.724276	73	1.863323	93	1.968483
14	1.146128	34	1.531479	54	1.732394	74	1.869232	94	1.973128
15	1.176091	35	1.544068	55	1.740363	75	1.875061	95	1.977724
16	1.204120	36	1.556303	56	1.748188	76	1.880814	96	1.982271
17	1.230449	37	1.568202	57	1.755875	77	1.886491	97	1.986772
18	1.255273	38	1.579784	58	1.763428	78	1.892095	98	1.991226
19	1.278754	39	1.591065	59	1.770852	79	1.897627	99	1.995635
20	1.301030	40	1.602060	60	1.778151	80	1.903090	100	2.000000

	Value at 0°.	Sign in 1st Quad.	Value at 90°.	Sign in 2d Quad.	Value at 180°.	Sign in 3d Quad.	Value at 270°	Sign in 4th Quad.	Value at 360°.
Sin........	O	+	R	+	O	−	R	−	O
Tan.......	O	+	∞	−	O	+	∞	−	O
Sec	R	+	∞	−	R	−	∞	+	R
Versin....	O	+	R	+	2 R	+	R	+	O
Cos	R	+	O	−	R	−	O	+	R
Cot.... ...	∞	+	O	−	∞	+	O	−	∞
Cosec.....	∞	+	R	+	∞	−	R	−	∞

R *signifies equal to rad*; ∞ signifies infinite; O signifies evanescent.

TABLE XXV.—LOGARITHMIC SINES

0°		Sine.	q −l		Tang.	Cotang.	q +l	D1″	Cosine.	179°
″	′		4.685				15.314			′
0	0	Inf. neg.	575	575	Inf. neg.	Inf. pos.	425		ten	60
60	1	6.463726	575	575	6.463726	13.536274	425		ten	59
120	2	.764756	575	575	.764756	.235244	425		ten	58
180	3	6.940847	575	575	6.940847	13.059153	425		ten	57
240	4	7.065786	575	575	7.065786	12.934214	425		ten	56
300	5	.162696	575	575	.162696	.837304	425		ten	55
360	6	.241877	575	575	.241878	.758122	425	.02	9.999999	54
420	7	.308824	575	575	.308825	.691175	425	.00	.999999	53
480	8	.366816	574	576	.366817	.633183	424	.00	.999999	52
540	9	.417968	574	576	.417970	.582030	424	.00	.999999	51
600	10	.463726	574	576	.463727	.536273	424	.02	.999998	50
660	11	7.505118	574	576	7.505120	12.494880	424	.00	9.999998	49
720	12	.542906	574	577	.542909	.457091	423	.02	.999997	48
780	13	.577668	574	577	.577672	.422328	423	.00	.999997	47
840	14	.609853	574	577	.609857	.390143	423	.02	.999996	46
900	15	.639816	573	578	.639820	.360180	422	.00	.999996	45
960	16	.667845	573	578	.667849	.332151	422	.02	.999995	44
1020	17	.694173	573	578	.694179	.305821	422	.00	.999995	43
1080	18	.718997	573	579	.719003	.280997	421	.02	.999994	42
1140	19	.742478	573	579	.742484	.257516	421	.02	.999993	41
1200	20	.764754	572	580	.764761	.235239	420	.00	.999993	40
1260	21	7.785943	572	580	7.785951	12.214049	420	.02	9.999992	39
1320	22	.806146	572	581	.806155	.193845	419	.02	.999991	38
1380	23	.825451	572	581	.825460	.174540	419	.02	.999990	37
1440	24	.842934	571	582	.843944	.156056	418	.02	.999989	36
1500	25	.861662	571	583	.861674	.138326	417	.00	.999989	35
1560	26	.878695	571	583	.878708	.121292	417	.02	.999988	34
1620	27	.895085	570	584	.895099	.104901	416	.02	.999987	33
1680	28	.910879	570	584	.910894	.089106	416	.02	.999986	32
1740	29	.926119	570	585	.926134	.073866	415	.02	.999985	31
1800	30	.940842	569	586	.940858	.059142	414	.03	.999983	30
1860	31	7.955082	569	587	7.955100	12.044900	413	.02	9.999982	29
1920	32	.968870	569	587	.968889	.031111	413	.02	.999981	28
1980	33	.982233	568	588	.982253	.017747	412	.02	.999980	27
2040	34	7.995198	568	589	7.995219	12.004781	411	.02	.999979	26
2100	35	8.007787	567	590	8.007809	11.992191	410	.03	.999977	25
2160	36	.020021	567	591	.020044	.979956	409	.02	.999976	24
2220	37	.031919	566	592	.031945	.968055	408	.02	.999975	23
2280	38	.043501	566	593	.043527	.956473	407	.03	.999973	22
2340	39	.054781	566	593	.054809	.945191	407	.02	.999972	21
2400	40	.065776	565	594	.065806	.934194	406	.02	.999971	20
2460	41	8.076500	565	595	8.076531	11.923469	405	.03	9.999969	19
2520	42	.086965	564	596	.086997	.913003	404	.02	.999968	18
2580	43	.097183	564	598	.097217	.902783	402	.03	.999966	17
2640	44	.107167	563	599	.107203	.892797	401	.03	.999964	16
2700	45	.116926	562	600	.116963	.883037	400	.02	.999963	15
2760	46	.126471	562	601	.126510	.873490	399	.03	.999961	14
2820	47	.135810	561	602	.135851	.864149	398	.03	.999959	13
2880	48	.144953	561	603	.144996	.855004	397	.02	.999958	12
2940	49	.153907	560	604	.153952	.846048	396	.03	.999956	11
3000	50	.162681	560	605	.162727	.837273	395	.03	.999954	10
3060	51	8.171280	559	607	8.171328	11.828672	393	.03	9.999952	9
3120	52	.179713	558	608	.179763	.820237	392	.03	.999950	8
3180	53	.187985	558	609	.188036	.811964	391	.03	.999948	7
3240	54	.196102	557	611	.196156	.803844	389	.03	.999946	6
3300	55	.204070	556	612	.204126	.795874	388	.03	.999944	5
3360	56	.211895	556	613	.211953	.788047	387	.03	.999942	4
3420	57	.219581	555	615	.219641	.780359	385	.03	.999940	3
3480	58	.227134	554	616	.227195	.772805	384	.03	.999938	2
3540	59	.234557	554	618	.234621	.765379	382	.03	.999936	1
3600	60	8.241855	553	619	8.241921	11.758079	381	.03	9.999934	0
″	′		4.685				15.314			′
90°		Cosine.	q −l		Cotang.	Tang.	q +l	D1″	Sine.	89°

1°		Sine.	q−l		Tang.	Cotang.	q+l	D1″	Cosine.	178°
″	′		4.685				15.314			′
3600	0	8.241855	553	619	8.241921	11.758079	381	.03	9.999934	60
3660	1	.249033	552	620	.249102	.750898	380	.05	.999932	59
3720	2	.256094	551	622	.256165	.743835	378	.03	.999929	58
3780	3	.263042	551	623	.263115	.736885	377	.03	.999927	57
3840	4	.269881	550	625	.269956	.730044	375	.05	.999925	56
3900	5	.276614	549	627	.276691	.723309	373	.03	.999922	55
3960	6	.283243	548	628	.283323	.716677	372	.03	.999920	54
4020	7	.289773	547	630	.289856	.710144	370	.05	.999918	53
4080	8	.296207	546	632	.296292	.703708	368	.03	.999915	52
4140	9	.302546	546	633	.302634	.697366	367	.05	.999913	51
4200	10	.308794	545	635	.308884	.691116	365	.05	.999910	50
4260	11	8.314954	544	637	8.315046	11.684954	363	.03	9.999907	49
4320	12	.321027	543	638	.321122	.678878	362	.05	.999905	48
4380	13	.327016	542	640	.327114	.672886	360	.05	.999902	47
4440	14	.332924	541	642	.333025	.666975	358	.03	.999899	46
4500	15	.338753	540	644	.338856	.661144	356	.05	.999897	45
4560	16	.344504	539	646	.344610	.655390	354	.05	.999894	44
4620	17	.350181	539	648	.350289	.649711	352	.05	.999891	43
4680	18	.355783	538	649	.355895	.644105	351	.05	.999888	42
4740	19	.361315	537	651	.361430	.638570	349	.05	.999885	41
4800	20	.366777	536	653	.366895	.633105	347	.05	.999882	40
4860	21	8.372171	535	655	8.372292	11.627708	345	.05	9.999879	39
4920	22	.377499	534	657	.377622	.622378	343	.05	.999876	38
4980	23	.382762	533	659	.382889	.617111	341	.05	.999873	37
5040	24	.387962	532	661	.388092	.611908	339	.05	.999870	36
5100	25	.393101	531	663	.393234	.606766	337	.05	.999867	35
5160	26	.398179	530	666	.398315	.601685	334	.05	.999864	34
5220	27	.403199	529	668	.403338	.596662	332	.05	.999861	33
5280	28	.408161	527	670	.408304	.591696	330	.07	.999858	32
5340	29	.413068	526	672	.413213	.586787	328	.05	.999854	31
5400	30	.417919	525	674	.418068	.581932	326	.05	.999851	30
5460	31	8.422717	524	676	8.422869	11.577131	324	.07	9.999848	29
5520	32	.427462	523	679	.427618	.572382	321	.05	.999844	28
5580	33	.432156	522	681	.432315	.567685	319	.05	.999841	27
5640	34	.436800	521	683	.436962	.563038	317	.07	.999838	26
5700	35	.441394	520	685	.441560	.558440	315	.05	.999834	25
5760	36	.445941	518	688	.446110	.553890	312	.07	.999831	24
5820	37	.450440	517	690	.450613	.549387	310	.05	.999827	23
5880	38	.454893	516	693	.455070	.544930	307	.07	.999824	22
5940	39	.459301	515	695	.459481	.540519	305	.07	.999820	21
6000	40	.463665	514	697	.463849	.536151	303	.05	.999816	20
6060	41	8.467985	512	700	8.468172	11.531828	300	.07	9.999813	19
6120	42	.472263	511	702	.472454	.527546	298	.07	.999809	18
6180	43	.476498	510	705	.476693	.523307	295	.07	.999805	17
6240	44	.480693	509	707	.480892	.519108	293	.07	.999801	16
6300	45	.484848	507	710	.485050	.514950	290	.05	.999797	15
6360	46	.488963	506	713	.489170	.510830	287	.07	.999794	14
6420	47	.493040	505	715	.493250	.506750	285	.07	.999790	13
6480	48	.497078	503	718	.497293	.502707	282	.07	.999786	12
6540	49	.501080	502	720	.501298	.498702	280	.07	.999782	11
6600	50	.505045	501	723	.505267	.494733	277	.07	.999778	10
6660	51	8.508974	499	726	8.509200	11.490800	274	.08	9.999774	9
6720	52	.512867	498	729	.513098	.486902	271	.07	.999769	8
6780	53	.516726	497	731	.516961	.483039	269	.07	.999765	7
6840	54	.520551	495	734	.520790	.479210	266	.07	.999761	6
6900	55	.524343	494	737	.524586	.475414	263	.07	.999757	5
6960	56	.528102	492	740	.528349	.471651	260	.08	.999753	4
7020	57	.531828	491	743	.532080	.467920	257	.07	.999748	3
7080	58	.535523	490	745	.535779	.464221	255	.07	.999744	2
7140	59	.539186	488	748	.539447	.460553	252	.08	.999740	1
7200	60	8.542819	487	751	8.543084	11.456916	249		9.999735	0
″	′		4.685				15.314			
91°		Cosine.	q−l		Cotang.	Tang.	q+l	D1″	Sine.	

2°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	177°
0'	8.542819	60.05	9.999735	.07	8.543084	60.12	11.456916	60'
1	.546422	59.55	.999731	.08	.546691	59.62	.453309	59
2	.549995	59.07	.999726	.07	.550268	59.15	.449732	58
3	.553539	58.58	.999722	.08	.553817	58.65	.446183	57
4	.557054	58.10	.999717	.07	.557336	58.20	.442664	56
5	.560540	57.65	.999713	.08	.560828	57.72	.439172	55
6	.563999	57.20	.999708	.07	.564291	57.27	.435709	54
7	.567431	56.75	.999704	.08	.567727	56.83	.432273	53
8	.570836	56.30	.999699	.08	.571137	56.38	.428863	52
9	.574214	55.87	.999694	.08	.574520	55.95	.425480	51
10	.577566	55.43	.999689	.07	.577877	55.52	.422123	50
11	8.580892	55.02	9.999685	.08	8.581208	55.10	11.418792	49
12	.584193	54.60	.999680	.08	.584514	54.68	.415486	48
13	.587469	54.20	.999675	.08	.587795	54.27	.412205	47
14	.590721	53.78	.999670	.08	.591051	53.87	.408949	46
15	.593948	53.40	.999665	.08	.594283	53.48	.405717	45
16	.597152	53.00	.999660	.08	.597492	53.08	.402508	44
17	.600332	52.62	.999655	.08	.600677	52.70	.399323	43
18	.603489	52.23	.999650	.08	.603839	52.32	.396161	42
19	.606623	51.85	.999645	.08	.606978	51.93	.393022	41
20	.609734	51.48	.999640	.08	.610094	51.58	.389906	40
21	8.612823	51.13	9.999635	.10	8.613189	51.22	11.386811	39
22	.615891	50.77	.999629	.08	.616262	50.85	.383738	38
23	.618937	50.42	.999624	.08	.619313	50.50	.380687	37
24	.621962	50.05	.999619	.08	.622343	50.15	.377657	36
25	.624965	49.72	.999614	.10	.625352	49.80	.374648	35
26	.627948	49.38	.999608	.08	.628340	49.47	.371660	34
27	.630911	49.05	.999603	.10	.631308	49.13	.368692	33
28	.633854	48.70	.999597	.08	.634256	48.80	.365744	32
29	.636776	48.40	.999592	.10	.637184	48.48	.362816	31
30	.639680	48.05	.999586	.08	.640093	48.15	.359907	30
31	8.642563	47.75	9.999581	.10	8.642982	47.85	11.357018	29
32	.645428	47.43	.999575	.08	.645853	47.52	.354147	28
33	.648274	47.13	.999570	.10	.648704	47.22	.351296	27
34	.651102	46.82	.999564	.10	.651537	46.92	.348463	26
35	.653911	46.52	.999558	.08	.654352	46.62	.345648	25
36	.656702	46.22	.999553	.10	.657149	46.32	.342851	24
37	.659475	45.92	.999547	.10	.659928	46.02	.340072	23
38	.662230	45.63	.999541	.10	.662689	45.73	.337311	22
39	.664968	45.35	.999535	.10	.665433	45.45	.334567	21
40	.667689	45.07	.999529	.08	.668160	45.17	.331840	20
41	8.670393	44.78	9.999524	.10	8.670870	44.88	11.329130	19
42	.673080	44.52	.999518	.10	.673563	44.60	.326437	18
43	.675751	44.23	.999512	.10	.676239	44.35	.323761	17
44	.678405	43.97	.999506	.10	.678900	44.07	.321100	16
45	.681043	43.70	.999500	.12	.681544	43.80	.318456	15
46	.683665	43.45	.999493	.10	.684172	43.53	.315828	14
47	.686272	43.18	.999487	.10	.686784	43.28	.313216	13
48	.688863	42.92	.999481	.10	.689381	43.03	.310619	12
49	.691438	42.67	.999475	.10	.691963	42.77	.308037	11
50	.693998	42.42	.999469	.10	.694529	42.53	.305471	10
51	8.696543	42.17	9.999463	.12	8.697081	42.27	11.302919	9
52	.699073	41.93	.999456	.10	.699617	42.03	.300383	8
53	.701589	41.68	.999450	.12	.702139	41.78	.297861	7
54	.704090	41.45	.999443	.10	.704646	41.57	.295354	6
55	.706577	41.20	.999437	.10	.707140	41.30	.292860	5
56	.709049	40.97	.999431	.12	.709618	41.08	.290382	4
57	.711507	40.75	.999424	.10	.712083	40.85	.287917	3
58	.713952	40.52	.999418	.12	.714534	40.63	.285466	2
59	.716383	40.28	.999411	.12	.716972	40.40	.283028	1
60'	8.718800		9.999404		8.719396		11.280604	0'
92°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	87°

3°	Sine.	D. 1″.	Cosine.	D. 1″.	Tang.	D. 1″.	Cotang.	176°
0′	8.718800	40.07	9.999404	.10	8.719396	40.17	11.280604	60′
1	.721204	39.85	.999398	.12	.721806	39.97	.278194	59
2	.723595	39.62	.999391	.12	.724204	39.73	.275796	58
3	.725972	39.42	.999384	.10	.726588	39.52	.273412	57
4	.728337	39.18	.999378	.12	.728959	39.30	.271041	56
5	.730688	38.98	.999371	.12	.731317	39.10	.268683	55
6	.733027	38.78	.999364	.12	.733663	38.88	.266337	54
7	.735354	38.55	.999357	.12	.735996	38.68	.264004	53
8	.737667	38.37	.999350	.12	.738317	38.48	.261683	52
9	.739969	38.17	.999343	.12	.740626	38.27	.259374	51
10	.742259	37.95	.999336	.12	.742922	38.08	.257078	50
11	8.744536	37.77	9.999329	.12	8.745207	37.87	11.254793	49
12	.746802	37.55	.999322	.12	.747479	37.68	.252521	48
13	.749055	37.37	.999315	.12	.749740	37.48	.250260	47
14	.751297	37.18	.999308	.12	.751989	37.30	.248011	46
15	.753528	36.98	.999301	.12	.754227	37.10	.245773	45
16	.755747	36.80	.999294	.12	.756453	36.92	.243547	44
17	.757955	36.60	.999287	.13	.758668	36.73	.241332	43
18	.760151	36.43	.999279	.12	.760872	36.55	.239128	42
19	.762337	36.23	.999272	.12	.763065	36.35	.236935	41
20	.764511	36.07	.999265	.13	.765246	36.18	.234754	40
21	8.766675	35.88	9.999257	.12	8.767417	36.02	11.232583	39
22	.768828	35.70	.999250	.13	.769578	35.82	.230422	38
23	.770970	35.52	.999242	.12	.771727	35.65	.228273	37
24	.773101	35.37	.999235	.13	.773866	35.48	.226134	36
25	.775223	35.17	.999227	.12	.775995	35.32	.224005	35
26	.777333	35.02	.999220	.13	.778114	35.13	.221886	34
27	.779434	34.88	.999212	.12	.780222	34.97	.219778	33
28	.781524	34.68	.999205	.13	.782320	34.80	.217680	32
29	.783605	34.50	.999197	.13	.784408	34.63	.215592	31
30	.785675	34.35	.999189	.13	.786486	34.47	.213514	30
31	8.787736	34.18	9.999181	.12	8.788554	34.32	11.211446	29
32	.789787	34.02	.999174	.13	.790613	34.15	.209387	28
33	.791828	33.85	.999166	.13	.792662	33.98	.207338	27
34	.793859	33.70	.999158	.13	.794701	33.83	.205299	26
35	.795881	33.55	.999150	.13	.796731	33.68	.203269	25
36	.797894	33.38	.999142	.13	.798752	33.52	.201248	24
37	.799897	33.25	.999134	.13	.800763	33.37	.199237	23
38	.801892	33.07	.999126	.13	.802765	33.22	.197235	22
39	.803876	32.93	.999118	.13	.804758	33.07	.195242	21
40	.805852	32.78	.999110	.13	.806742	32.92	.193258	20
41	8.807819	32.63	9.999102	.13	8.808717	32.77	11.191283	19
42	.809777	32.48	.999094	.13	.810683	32.63	.189317	18
43	.811726	32.35	.999086	.15	.812641	32.47	.187359	17
44	.813667	32.20	.999077	.13	.814589	32.33	.185411	16
45	.815599	32.05	.999069	.13	.816529	32.20	.183471	15
46	.817522	31.90	.999061	.13	.818461	32.05	.181539	14
47	.819436	31.78	.999053	.15	.820384	31.90	.179616	13
48	.821343	31.62	.999044	.13	.822298	31.78	.177702	12
49	.823240	31.50	.999036	.15	.824205	31.63	.175795	11
50	.825130	31.35	.999027	.13	.826103	31.48	.173897	10
51	8.827011	31.22	9.999019	.15	8.827992	31.37	11.172008	9
52	.828884	31.08	.999010	.13	.829874	31.23	.170126	8
53	.830749	30.97	.999002	.15	.831748	31.08	.168252	7
54	.832607	30.82	.998993	.15	.833613	30.97	.166387	6
55	.834456	30.68	.998984	.13	.835471	30.83	.164529	5
56	.836297	30.55	.998976	.15	.837321	30.70	.162679	4
57	.838130	30.43	.998967	.15	.839163	30.58	.160837	3
58	.839956	30.30	.998958	.13	.840998	30.45	.159002	2
59	.841774	30.18	.998950	.15	.842825	30.32	.157175	1
60′	8.843585		9.998941		8.844644		11.155356	0′
93°	Cosine.	D 1″.	Sine.	D. 1″.	Cotang.	D. 1″.	Tang.	86°

N.	0	1	2	3	4	5	6	7	8	9	Diff.
765	883661	3718	3775	3832	3888	3945	4002	4059	4115	4172	
6	4229	4285	4342	4399	4455	4512	4569	4625	4682	4739	
7	4795	4852	4909	4965	5022	5078	5135	5192	5248	5305	
8	5361	5418	5474	5531	5587	5644	5700	5757	5813	5870	
9	5926	5983	6039	6096	6152	6209	6265	6321	6378	6434	
770	6491	6547	6604	6660	6716	6773	6829	6885	6942	6998	
1	7054	7111	7167	7223	7280	7336	7392	7449	7505	7561	
2	7617	7674	7730	7786	7842	7898	7955	8011	8067	8123	
3	8179	8236	8292	8348	8404	8460	8516	8573	8629	8685	
4	8741	8797	8853	8909	8965	9021	9077	9134	9190	9246	
5	9302	9358	9414	9470	9526	9582	9638	9694	9750	9806	56
6	9862	9918	9974	0030	0086	0141	0197	0253	0309	0365	
7	890421	0477	0533	0589	0645	0700	0756	0812	0868	0924	
8	0980	1035	1091	1147	1203	1259	1314	1370	1426	1482	
9	1537	1593	1649	1705	1760	1816	1872	1928	1983	2039	
780	2095	2150	2206	2262	2317	2373	2429	2484	2540	2595	
1	2651	2707	2762	2818	2873	2929	2985	3040	3096	3151	
2	3207	3262	3318	3373	3429	3484	3540	3595	3651	3706	
3	3762	3817	3873	3928	3984	4039	4094	4150	4205	4261	
4	4316	4371	4427	4482	4538	4593	4648	4704	4759	4814	
5	4870	4925	4980	5036	5091	5146	5201	5257	5312	5367	
6	5423	5478	5533	5588	5644	5699	5754	5809	5864	5920	
7	5975	6030	6085	6140	6195	6251	6306	6361	6416	6471	
8	6526	6581	6636	6692	6747	6802	6857	6912	6967	7022	
9	7077	7132	7187	7242	7297	7352	7407	7462	7517	7572	55
790	7627	7682	7737	7792	7847	7902	7957	8012	8067	8122	
1	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	
2	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	
3	9273	9328	9383	9437	9492	9547	9602	9656	9711	9766	
4	9821	9875	9930	9985	0039	0094	0149	0203	0258	0312	
5	900367	0422	0476	0531	0586	0640	0695	0749	0804	0859	
6	0913	0968	1022	1077	1131	1186	1240	1295	1349	1404	
7	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	
8	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	
9	2547	2601	2655	2710	2764	2818	2873	2927	2981	3036	
800	3090	3144	3199	3253	3307	3361	3416	3470	3524	3578	
1	3633	3687	3741	3795	3849	3904	3958	4012	4066	4120	
2	4174	4229	4283	4337	4391	4445	4499	4553	4607	4661	
3	4716	4770	4824	4878	4932	4986	5040	5094	5148	5202	
4	5256	5310	5364	5418	5472	5526	5580	5634	5688	5742	54
5	5796	5850	5904	5958	6012	6066	6119	6173	6227	6281	
6	6335	6389	6443	6497	6551	6604	6658	6712	6766	6820	
7	6874	6927	6981	7035	7089	7143	7196	7250	7304	7358	
8	7411	7465	7519	7573	7626	7680	7734	7787	7841	7895	
9	7949	8002	8056	8110	8163	8217	8270	8324	8378	8431	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
57	5.7	11.4	17.1	22.8	28.5	34.2	39.9	45.6	51.3
56	5.6	11.2	16.8	22.4	28.0	33.6	39.2	44.8	50.4
55	5.5	11.0	16.5	22.0	27.5	33.0	38.5	44.0	49.5
54	5.4	10.8	16.2	21.6	27.0	32.4	37.8	43.2	48.6

N.	0	1	2	3	4	5	6	7	8	9	Diff.
810	908485	8539	8592	8646	8699	8753	8807	8860	8914	8967	
1	9021	9074	9128	9181	9235	9289	9342	9396	9449	9503	
2	9556	9610	9663	9716	9770	9823	9877	9930	9984	0037	
3	910091	0144	0197	0251	0304	0358	0411	0464	0518	0571	
4	0624	0678	0731	0784	0838	0891	0944	0998	1051	1104	
5	1158	1211	1264	1317	1371	1424	1477	1530	1584	1637	
6	1690	1743	1797	1850	1903	1956	2009	2063	2116	2169	
7	2222	2275	2328	2381	2435	2488	2541	2594	2647	2700	
8	2753	2806	2859	2913	2966	3019	3072	3125	3178	3231	
9	3284	3337	3390	3443	3496	3549	3602	3655	3708	3761	53
820	3814	3867	3920	3973	4026	4079	4132	4184	4237	4290	
1	4343	4396	4449	4502	4555	4608	4660	4713	4766	4819	
2	4872	4925	4977	5030	5083	5136	5189	5241	5294	5347	
3	5400	5453	5505	5558	5611	5664	5716	5769	5822	5875	
4	5927	5980	6033	6085	6138	6191	6243	6296	6349	6401	
5	6454	6507	6559	6612	6664	6717	6770	6822	6875	6927	
6	6980	7033	7085	7138	7190	7243	7295	7348	7400	7453	
7	7506	7558	7611	7663	7716	7768	7820	7873	7925	7978	
8	8030	8083	8135	8188	8240	8293	8345	8397	8450	8502	
9	8555	8607	8659	8712	8764	8816	8869	8921	8973	9026	
830	9078	9130	9183	9235	9287	9340	9392	9444	9496	9549	
1	9601	9653	9706	9758	9810	9862	9914	9967	0019	0071	
2	920123	0176	0228	0280	0332	0384	0436	0489	0541	0593	
3	0645	0697	0749	0801	0853	0906	0958	1010	1062	1114	
4	1166	1218	1270	1322	1374	1426	1478	1530	1582	1634	52
5	1686	1738	1790	1842	1894	1946	1998	2050	2102	2154	
6	2206	2258	2310	2362	2414	2466	2518	2570	2622	2674	
7	2725	2777	2829	2881	2933	2985	3037	3089	3140	3192	
8	3244	3296	3348	3399	3451	3503	3555	3607	3658	3710	
9	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	
840	4279	4331	4383	4434	4486	4538	4589	4641	4693	4744	
1	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	
2	5312	5364	5415	5467	5518	5570	5621	5673	5725	5776	
3	5828	5879	5931	5982	6034	6085	6137	6188	6240	6291	
4	6342	6394	6445	6497	6548	6600	6651	6702	6754	6805	
5	6857	6908	6959	7011	7062	7114	7165	7216	7268	7319	
6	7370	7422	7473	7524	7576	7627	7678	7730	7781	7832	
7	7883	7935	7986	8037	8088	8140	8191	8242	8293	8345	
8	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	
9	8908	8959	9010	9061	9112	9163	9215	9266	9317	9368	
850	9419	9470	9521	9572	9623	9674	9725	9776	9827	9879	
1	9930	9981	0032	0083	0134	0185	0236	0287	0338	0389	51
2	930440	0491	0542	0592	0643	0694	0745	0796	0847	0898	
3	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	
4	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
53	5.3	10.6	15.9	21.2	26.5	31.8	37.1	42.4	47.7
52	5.2	10.4	15.6	20.8	26.0	31.2	36.4	41.6	46.8
51	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	45
50	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	4

N.	0	1	2	3	4	5	6	7	8	9	Diff.
945	975432	5478	5524	5570	5616	5662	5707	5753	5799	5845	
6	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	
7	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	
8	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	
9	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	
950	7724	7769	7815	7861	7906	7952	7998	8043	8089	8135	
1	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	
2	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	
3	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	
4	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	
5	980003	0049	0094	0140	0185	0231	0276	0322	0367	0412	
6	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	
7	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	
8	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	
9	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	
960	2271	2316	2362	2407	2452	2497	2543	2588	2633	2678	
1	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	
2	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	
3	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	
4	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	
5	4527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
6	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	
7	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	
8	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	
9	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	
970	6772	6817	6861	6906	6951	6996	7040	7085	7130	7175	
1	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	
2	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	
3	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	
4	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	
5	9005	9049	9094	9138	9183	9227	9272	9316	9361	9405	
6	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	
7	9895	9939	9983	0028	0072	0117	0161	0206	0250	0294	
8	990339	0383	0428	0472	0516	0561	0605	0650	0694	0738	
9	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	
980	1226	1270	1315	1359	1403	1448	1492	1536	1580	1625	
1	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	
2	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	
3	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	
4	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	
5	3436	3480	3524	3568	3613	3657	3701	3745	3789	3833	
6	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	
7	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
8	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	
9	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
[illegible]	4.6	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41.4
[illegible]	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5
[illegible]	4.4	8.8	13.2	17.6	22.0	26.4	30.8	35.2	39.
[illegible]	4.3	8.6	12.9	17.2	21.5	25.8	30.1	34.4	38

N.	0	1	2	3	4	5	6	7	8	9	Diff.
900	954243	4291	4339	4387	4435	4484	4532	4580	4628	4677	
1	4725	4773	4821	4869	4918	4966	5014	5062	5110	5158	
2	5207	5255	5303	5351	5399	5447	5495	5543	5592	5640	
3	5688	5736	5784	5832	5880	5928	5976	6024	6072	6120	
4	6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	
5	6649	6697	6745	6793	6840	6888	6936	6984	7032	7080	48
6	7128	7176	7224	7272	7320	7368	7416	7464	7512	7559	
7	7607	7655	7703	7751	7799	7847	7894	7942	7990	8038	
8	8086	8134	8181	8229	8277	8325	8373	8421	8468	8516	
9	8564	8612	8659	8707	8755	8803	8850	8898	8946	8994	
910	9041	9089	9137	9185	9232	9280	9328	9375	9423	9471	
1	9518	9566	9614	9661	9709	9757	9804	9852	9900	9947	
2	9995	0042	0090	0138	0185	0233	0280	0328	0376	0423	
3	960471	0518	0566	0613	0661	0709	0756	0804	0851	0899	
4	0946	0994	1041	1089	1136	1184	1231	1279	1326	1374	
5	1421	1469	1516	1563	1611	1658	1706	1753	1801	1848	
6	1895	1943	1990	2038	2085	2132	2180	2227	2275	2322	
7	2369	2417	2464	2511	2559	2606	2653	2701	2748	2795	
8	2843	2890	2937	2985	3032	3079	3126	3174	3221	3268	
9	3316	3363	3410	3457	3504	3552	3599	3646	3693	3741	
920	3788	3835	3882	3929	3977	4024	4071	4118	4165	4212	
1	4260	4307	4354	4401	4448	4495	4542	4590	4637	4684	
2	4731	4778	4825	4872	4919	4966	5013	5061	5108	5155	
3	5202	5249	5296	5343	5390	5437	5484	5531	5578	5625	
4	5672	5719	5766	5813	5860	5907	5954	6001	6048	6095	47
5	6142	6189	6236	6283	6329	6376	6423	6470	6517	6564	
6	6611	6658	6705	6752	6799	6845	6892	6939	6986	7033	
7	7080	7127	7173	7220	7267	7314	7361	7408	7454	7501	
8	7548	7595	7642	7688	7735	7782	7829	7875	7922	7969	
9	8016	8062	8109	8156	8203	8249	8296	8343	8390	8436	
930	8483	8530	8576	8623	8670	8716	8763	8810	8856	8903	
1	8950	8996	9043	9090	9136	9183	9229	9276	9323	9369	
2	9416	9463	9509	9556	9602	9649	9695	9742	9789	9835	
3	9882	9928	9975	0021	0068	0114	0161	0207	0254	0300	
4	970347	0393	0440	0486	0533	0579	0626	0672	0719	0765	
5	0812	0858	0904	0951	0997	1044	1090	1137	1183	1229	
6	1276	1322	1369	1415	1461	1508	1554	1601	1647	1693	
7	1740	1786	1832	1879	1925	1971	2018	2064	2110	2157	
8	2203	2249	2295	2342	2388	2434	2481	2527	2573	2619	
9	2666	2712	2758	2804	2851	2897	2943	2989	3035	3082	
940	3128	3174	3220	3266	3313	3359	3405	3451	3497	3543	
1	3590	3636	3682	3728	3774	3820	3866	3913	3959	4005	
2	4051	4097	4143	4189	4235	4281	4327	4374	4420	4466	
3	4512	4558	4604	4650	4696	4742	4788	4834	4880	4926	
4	4972	5018	5064	5110	5156	5202	5248	5294	5340	5386	46

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
47	4.7	9.4	14.1	18.8	23.5	28.2	32.9	37.6	42.3
46	4.6	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41

N.	0	1	2	3	4	5	6	7	8	9	Diff.
945	975432	5478	5524	5570	5616	5662	5707	5753	5799	5845	
6	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	
7	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	
8	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	
9	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	
950	7724	7769	7815	7861	7906	7952	7998	8043	8089	8135	
1	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	
2	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	
3	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	
4	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	
5	980003	0049	0094	0140	0185	0231	0276	0322	0367	0412	
6	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	
7	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	
8	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	
9	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	
960	2271	2316	2362	2407	2452	2497	2543	2588	2633	2678	
1	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	
2	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	
3	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	
4	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	
5	4527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
6	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	
7	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	
8	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	
9	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	
970	6772	6817	6861	6906	6951	6996	7040	7085	7130	7175	
1	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	
2	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	
3	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	
4	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	
5	9005	9049	9094	9138	9183	9227	9272	9316	9361	9405	
6	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	
7	9895	9939	9983	0028	0072	0117	0161	0206	0250	0294	
8	990339	0383	0428	0472	0516	0561	0605	0650	0694	0738	
9	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	
980	1226	1270	1315	1359	1403	1448	1492	1536	1580	1625	
1	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	
2	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	
3	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	
4	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	
5	3436	3480	3524	3568	3613	3657	3701	3745	3789	3833	
6	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	
7	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
8	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	
9	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
46	4.6	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41.4
[illegible]	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5
[illegible]	4.4	8.8	13.2	17.6	22.0	26.4	30.8	35.2	39.6
[illegible]	4.3	8.6	12.9	17.2	21.5	25.8	30.1	34.4	38.7

No. 990 L. 995.] [No. 999 L. 999.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
990	995635	5679	5723	5767	5811	5854	5898	5942	5986	6030	
1	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
2	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	
3	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	
4	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	
5	7823	7867	7910	7954	7998	8041	8085	8129	8172	8216	
6	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	
7	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	
8	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	
9	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43

LOGARITHMS OF NUMBERS FROM 1 TO 100.

N.	Log.	N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0.000000	21	1.322219	41	1.612784	61	1.785330	81	1.908485
2	0.301030	22	1.342423	42	1.623249	62	1.792392	82	1.913814
3	0.477121	23	1.361728	43	1.633468	63	1.799341	83	1.919078
4	0.602060	24	1.380211	44	1.643453	64	1.806180	84	1.924279
5	0.698970	25	1.397940	45	1.653213	65	1.812913	85	1.929419
6	0.778151	26	1.414973	46	1.662758	66	1.819544	86	1.934498
7	0.845098	27	1.431364	47	1.672098	67	1.826075	87	1.939519
8	0.903090	28	1.447158	48	1.681241	68	1.832509	88	1.944483
9	0.954243	29	1.462398	49	1.690196	69	1.838849	89	1.949390
10	1.000000	30	1.477121	50	1.698970	70	1.845098	90	1.954243
11	1.041393	31	1.491362	51	1.707570	71	1.851258	91	1.959041
12	1.079181	32	1.505150	52	1.716003	72	1.857332	92	1.963788
13	1.113943	33	1.518514	53	1.724276	73	1.863323	93	1.968483
14	1.146128	34	1.531479	54	1.732394	74	1.869232	94	1.973128
15	1.176091	35	1.544068	55	1.740363	75	1.875061	95	1.977724
16	1.204120	36	1.556303	56	1.748188	76	1.880814	96	1.982271
17	1.230449	37	1.568202	57	1.755875	77	1.886491	97	1.986772
18	1.255273	38	1.579784	58	1.763428	78	1.892095	98	1.991226
19	1.278754	39	1.591065	59	1.770852	79	1.897627	99	1.995635
20	1.301030	40	1.602060	60	1.778151	80	1.903090	100	2.000000

	Value at 0°.	Sign in 1st Quad.	Value at 90°.	Sign in 2d Quad.	Value at 180°.	Sign in 3d Quad.	Value at 270°	Sign in 4th Quad.	Value at 360°.
Sin........	O	+	R	+	O	−	R	−	O
Tan.......	O	+	∞	−	O	+	∞	−	O
Sec	R	+	∞	−	R	−	∞	+	R
Versin....	O	+	R	+	2 R	+	R	+	O
Cos	R	+	O	−	R	−	O	+	R
Cot.... ...	∞	+	O	−	∞	+	O	−	∞
Cosec.....	∞	+	R	+	∞	−	R	−	∞

R signifies equal to rad; ∞ signifies infinite; O signifies evanescent.

0°		Sine.	q−l		Tang.	Cotang.	q+l	Dl″	Cosine.	179°
″	′		4.685				15.314			′
0	0	Inf. neg.	575	575	Inf. neg.	Inf. pos.	425		ten	60
60	1	6.463726	575	575	6.463726	13.536274	425		ten	59
120	2	.764756	575	575	.764756	.235244	425		ten	58
180	3	6.940847	575	575	6.940847	13.059153	425		ten	57
240	4	7.065786	575	575	7.065786	12.934214	425		ten	56
300	5	.162696	575	575	.162696	.837304	425		ten	55
360	6	.241877	575	575	.241878	.758122	425	.02	9.999999	54
420	7	.308824	575	575	.308825	.691175	425	.00	.999999	53
480	8	.366816	574	576	.366817	.633183	424	.00	.999999	52
540	9	.417968	574	576	.417970	.582030	424	.00	.999999	51
600	10	.463726	574	576	.463727	.536273	424	.02	.999998	50
660	11	7.505118	574	576	7.505120	12.494880	424	.00	9.999998	49
720	12	.542906	574	577	.542909	.457091	423	.02	.999997	48
780	13	.577668	574	577	.577672	.422328	423	.00	.999997	47
840	14	.609853	574	577	.609857	.390143	423	.02	.999996	46
900	15	.639816	573	578	.639820	.360180	422	.00	.999996	45
960	16	.667845	573	578	.667849	.332151	422	.02	.999995	44
1020	17	.694173	573	578	.694179	.305821	422	.00	.999995	43
1080	18	.718997	573	579	.719003	.280997	421	.02	.999994	42
1140	19	.742478	573	579	.742484	.257516	421	.02	.999993	41
1200	20	.764754	572	580	.764761	.235239	420	.00	.999993	40
1260	21	7.785943	572	580	7.785951	12.214049	420	.02	9.999992	39
1320	22	.806146	572	581	.806155	.193845	419	.02	.999991	38
1380	23	.825451	572	581	.825460	.174540	419	.02	.999990	37
1440	24	.842934	571	582	.843944	.156056	418	.02	.999989	36
1500	25	.861662	571	583	.861674	.138326	417	.00	.999989	35
1560	26	.878695	571	583	.878708	.121292	417	.02	.999988	34
1620	27	.895085	570	584	.895099	.104901	416	.02	.999987	33
1680	28	.910879	570	584	.910894	.089106	416	.02	.999986	32
1740	29	.926119	570	585	.926134	.073866	415	.02	.999985	31
1800	30	.940842	569	586	.940858	.059142	414	.03	.999983	30
1860	31	7.955082	569	587	7.955100	12.044900	413	.02	9.999982	29
1920	32	.968870	569	587	.968889	.031111	413	.02	.999981	28
1980	33	.982233	568	588	.982253	.017747	412	.02	.999980	27
2040	34	7.995198	568	589	7.995219	12.004781	411	.02	.999979	26
2100	35	8.007787	567	590	8.007809	11.992191	410	.03	.999977	25
2160	36	.020021	567	591	.020044	.979956	409	.02	.999976	24
2220	37	.031919	566	592	.031945	.968055	408	.02	.999975	23
2280	38	.043501	566	593	.043527	.956473	407	.03	.999973	22
2340	39	.054781	566	593	.054809	.945191	407	.02	.999972	21
2400	40	.065776	565	594	.065806	.934194	406	.02	.999971	20
2460	41	8.076500	565	595	8.076531	11.923469	405	.03	9.999969	19
2520	42	.086965	564	596	.086997	.913003	404	.02	.999968	18
2580	43	.097183	564	598	.097217	.902783	402	.03	.999966	17
2640	44	.107167	563	599	.107203	.892797	401	.03	.999964	16
2700	45	.116926	562	600	.116963	.883037	400	.02	.999963	15
2760	46	.126471	562	601	.126510	.873490	399	.03	.999961	14
2820	47	.135810	561	602	.135851	.864149	398	.03	.999959	13
2880	48	.144953	561	603	.144996	.855004	397	.02	.999958	12
2940	49	.153907	560	604	.153952	.846048	396	.03	.999956	11
3000	50	.162681	560	605	.162727	.837273	395	.03	.999954	10
3060	51	8.171280	559	607	8.171328	11.828672	393	.03	9.999952	9
3120	52	.179713	558	608	.179763	.820237	392	.03	.999950	8
3180	53	.187985	558	609	.188036	.811964	391	.03	.999948	7
3240	54	.196102	557	611	.196156	.803844	389	.03	.999946	6
3300	55	.204070	556	612	.204126	.795874	388	.03	.999944	5
3360	56	.211895	556	613	.211953	.788047	387	.03	.999942	4
3420	57	.219581	555	615	.219641	.780359	385	.03	.999940	3
3480	58	.227134	554	616	.227195	.772805	384	.03	.999938	2
3540	59	.234557	554	618	.234621	.765379	382	.03	.999936	1
3600	60	8.241855	553	619	8.241921	11.758079	381	.03	9.999934	0
″	′		4.685				15.314			′
		Cosine.	q−l		Cotang.	Tang.	q+l	Dl″	Sine.	

1°		Sine.	$q-l$		Tang.	Cotang.	$q+l$	$D1''$	Cosine.	178°
″	′		4.685				15.314			′
3600	0	8.241855	553	619	8.241921	11.758079	381	.03	9.999934	60
3660	1	.249033	552	620	.249102	.750898	380	.05	.999932	59
3720	2	.256094	551	622	.256165	.743835	378	.03	.999929	58
3780	3	.263042	551	623	.263115	.736885	377	.03	.999927	57
3840	4	.269881	550	625	.269956	.730044	375	.05	.999925	56
3900	5	.276614	549	627	.276691	.723309	373	.03	.999922	55
3960	6	.283243	548	628	.283323	.716677	372	.03	.999920	54
4020	7	.289773	547	630	.289856	.710144	370	.05	.999918	53
4080	8	.296207	546	632	.296292	.703708	368	.03	.999915	52
4140	9	.302546	546	633	.302634	.697366	367	.05	.999913	51
4200	10	.308794	545	635	.308884	.691116	365	.05	.999910	50
4260	11	8.314954	544	637	8.315046	11.684954	363	.03	9.999907	49
4320	12	.321027	543	638	.321122	.678878	362	.05	.999905	48
4380	13	.327016	542	640	.327114	.672886	360	.05	.999902	47
4440	14	.332924	541	642	.333025	.666975	358	.03	.999899	46
4500	15	.338753	540	644	.338856	.661144	356	.05	.999897	45
4560	16	.344504	539	646	.344610	.655390	354	.05	.999894	44
4620	17	.350181	539	648	.350289	.649711	352	.05	.999891	43
4680	18	.355783	538	649	.355895	.644105	351	.05	.999888	42
4740	19	.361315	537	651	.361430	.638570	349	.05	.999885	41
4800	20	.366777	536	653	.366895	.633105	347	.05	.999882	40
4860	21	8.372171	535	655	8.372292	11.627708	345	.05	9.999879	39
4920	22	.377499	534	657	.377622	.622378	343	.05	.999876	38
4980	23	.382762	533	659	.382889	.617111	341	.05	.999873	37
5040	24	.387962	532	661	.388092	.611908	339	.05	.999870	36
5100	25	.393101	531	663	.393234	.606766	337	.05	.999867	35
5160	26	.398179	530	666	.398315	.601685	334	.05	.999864	34
5220	27	.403199	529	668	.403338	.596662	332	.05	.999861	33
5280	28	.408161	527	670	.408304	.591696	330	.07	.999858	32
5340	29	.413068	526	672	.413213	.586787	328	.05	.999854	31
5400	30	.417919	525	674	.418068	.581932	326	.05	.999851	30
5460	31	8.422717	524	676	8.422869	11.577131	324	.07	9.999848	29
5520	32	.427462	523	679	.427618	.572382	321	.05	.999844	28
5580	33	.432156	522	681	.432315	.567685	319	.05	.999841	27
5640	34	.436800	521	683	.436962	.563038	317	.07	.999838	26
5700	35	.441394	520	685	.441560	.558440	315	.05	.999834	25
5760	36	.445941	518	688	.446110	.553890	312	.07	.999831	24
5820	37	.450440	517	690	.450613	.549387	310	.05	.999827	23
5880	38	.454893	516	693	.455070	.544930	307	.07	.999824	22
5940	39	.459301	515	695	.459481	.540519	305	.07	.999820	21
6000	40	.463665	514	697	.463849	.536151	303	.05	.999816	20
6060	41	8.467985	512	700	8.468172	11.531828	300	.07	9.999813	19
6120	42	.472263	511	702	.472454	.527546	298	.07	.999809	18
6180	43	.476498	510	705	.476693	.523307	295	.07	.999805	17
6240	44	.480693	509	707	.480892	.519108	293	.07	.999801	16
6300	45	.484848	507	710	.485050	.514950	290	.05	.999797	15
6360	46	.488963	506	713	.489170	.510830	287	.07	.999794	14
6420	47	.493040	505	715	.493250	.506750	285	.07	.999790	13
6480	48	.497078	503	718	.497293	.502707	282	.07	.999786	12
6540	49	.501080	502	720	.501298	.498702	280	.07	.999782	11
6600	50	.505045	501	723	.505267	.494733	277	.07	.999778	10
6660	51	8.508974	499	726	8.509200	11.490800	274	.08	9.999774	9
6720	52	.512867	498	729	.513098	.486902	271	.07	.999769	8
6780	53	.516726	497	731	.516961	.483039	269	.07	.999765	7
6840	54	.520551	495	734	.520790	.479210	266	.07	.999761	6
6900	55	.524343	494	737	.524586	.475414	263	.07	.999757	5
6960	56	.528102	492	740	.528349	.471651	260	.08	.999753	4
7020	57	.531828	491	743	.532080	.467920	257	.07	.999748	3
7080	58	.535523	490	745	.535779	.464221	255	.07	.999744	2
7140	59	.539186	488	748	.539447	.460553	252	.08	.999740	1
7200	60	8.542819	487	751	8.543084	11.456916	249		9.999735	
″	′		4.685				15.314			
91°		Cosine.	$q-l$		Cotang.	Tang.	$q+l$	$D1''$	Sine.	

2°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	177°
0'	8.542819	60.05	9.999735	.07	8.543084	60.12	11.456916	60'
1	.546422	59.55	.999731	.08	.546691	59.62	.453309	59
2	.549995	59.07	.999726	.07	.550268	59.15	.449732	58
3	.553539	58.58	.999722	.08	.553817	58.65	.446183	57
4	.557054	58.10	.999717	.07	.557336	58.20	.442664	56
5	.560540	57.65	.999713	.08	.560828	57.72	.439172	55
6	.563999	57.20	.999708	.07	.564291	57.27	.435709	54
7	.567431	56.75	.999704	.08	.567727	56.83	.432273	53
8	.570836	56.30	.999699	.08	.571137	56.38	.428863	52
9	.574214	55.87	.999694	.08	.574520	55.95	.425480	51
10	.577566	55.43	.999689	.07	.577877	55.52	.422123	50
11	8.580892	55.02	9.999685	.08	8.581208	55.10	11.418792	49
12	.584193	54.60	.999680	.08	.584514	54.68	.415486	48
13	.587469	54.20	.999675	.08	.587795	54.27	.412205	47
14	.590721	53.78	.999670	.08	.591051	53.87	.408949	46
15	.593948	53.40	.999665	.08	.594283	53.48	.405717	45
16	.597152	53.00	.999660	.08	.597492	53.08	.402508	44
17	.600332	52.62	.999655	.08	.600677	52.70	.399323	43
18	.603489	52.23	.999650	.08	.603839	52.32	.396161	42
19	.606623	51.85	.999645	.08	.606978	51.93	.393022	41
20	.609734	51.48	.999640	.08	.610094	51.58	.389906	40
21	8.612823	51.13	9.999635	.10	8.613189	51.22	11.386811	39
22	.615891	50.77	.999629	.08	.616262	50.85	.383738	38
23	.618937	50.42	.999624	.08	.619313	50.50	.380687	37
24	.621962	50.05	.999619	.08	.622343	50.15	.377657	36
25	.624965	49.72	.999614	.10	.625352	49.80	.374648	35
26	.627948	49.38	.999608	.08	.628340	49.47	.371660	34
27	.630911	49.05	.999603	.10	.631308	49.13	.368692	33
28	.633854	48.70	.999597	.08	.634256	48.80	.365744	32
29	.636776	48.40	.999592	.10	.637184	48.48	.362816	31
30	.639680	48.05	.999586	.08	.640093	48.15	.359907	30
31	8.642563	47.75	9.999581	.10	8.642982	47.85	11.357018	29
32	.645428	47.43	.999575	.08	.645853	47.52	.354147	28
33	.648274	47.13	.999570	.10	.648704	47.22	.351296	27
34	.651102	46.82	.999564	.10	.651537	46.92	.348463	26
35	.653911	46.52	.999558	.08	.654352	46.62	.345648	25
36	.656702	46.22	.999553	.10	.657149	46.32	.342851	24
37	.659475	45.92	.999547	.10	.659928	46.02	.340072	23
38	.662230	45.63	.999541	.10	.662689	45.73	.337311	22
39	.664968	45.35	.999535	.10	.665433	45.45	.334567	21
40	.667689	45.07	.999529	.08	.668160	45.17	.331840	20
41	8.670393	44.78	9.999524	.10	8.670870	44.88	11.329130	19
42	.673080	44.52	.999518	.10	.673563	44.60	.326437	18
43	.675751	44.23	.999512	.10	.676239	44.35	.323761	17
44	.678405	43.97	.999506	.10	.678900	44.07	.321100	16
45	.681043	43.70	.999500	.12	.681544	43.80	.318456	15
46	.683665	43.45	.999493	.10	.684172	43.53	.315828	14
47	.686272	43.18	.999487	.10	.686784	43.28	.313216	13
48	.688863	42.92	.999481	.10	.689381	43.03	.310619	12
49	.691438	42.67	.999475	.10	.691963	42.77	.308037	11
50	.693998	42.42	.999469	.10	.694529	42.53	.305471	10
51	8.696543	42.17	9.999463	.12	8.697081	42.27	11.302919	9
52	.699073	41.93	.999456	.10	.699617	42.03	.300383	8
53	.701589	41.68	.999450	.12	.702139	41.78	.297861	7
54	.704090	41.45	.999443	.10	.704646	41.57	.295354	6
55	.706577	41.20	.999437	.10	.707140	41.30	.292860	5
56	.709049	40.97	.999431	.12	.709618	41.08	.290382	4
57	.711507	40.75	.999424	.10	.712083	40.85	.287917	3
58	.713952	40.52	.999418	.12	.714534	40.63	.285466	2
59	.716383	40.28	.999411	.12	.716972	40.40	.283028	1
60	8.718800		9.999404		8.719396		11.280604	0
	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	87°

3°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	176°
0′	8.718800	40.07	9.999404	.10	8.719396	40.17	11.280604	60′
1	.721204	39.85	.999398	.12	.721806	39.97	.278194	59
2	.723595	39.62	.999391	.12	.724204	39.73	.275796	58
3	.725972	39.42	.999384	.10	.726588	39.52	.273412	57
4	.728337	39.18	.999378	.12	.728959	39.30	.271041	56
5	.730688	38.98	.999371	.12	.731317	39.10	.268683	55
6	.733027	38.78	.999364	.12	.733663	38.88	.266337	54
7	.735354	38.55	.999357	.12	.735996	38.68	.264004	53
8	.737667	38.37	.999350	.12	.738317	38.48	.261683	52
9	.739969	38.17	.999343	.12	.740626	38.27	.259374	51
10	.742259	37.95	.999336	.12	.742922	38.08	.257078	50
11	8.744536	37.77	9.999329	.12	8.745207	37.87	11.254793	49
12	.746802	37.55	.999322	.12	.747479	37.68	.252521	48
13	.749055	37.37	.999315	.12	.749740	37.48	.250260	47
14	.751297	37.18	.999308	.12	.751989	37.30	.248011	46
15	.753528	36.98	.999301	.12	.754227	37.10	.245773	45
16	.755747	36.80	.999294	.12	.756453	36.92	.243547	44
17	.757955	36.60	.999287	.13	.758668	36.73	.241332	43
18	.760151	36.43	.999279	.12	.760872	36.55	.239128	42
19	.762337	36.23	.999272	.12	.763065	36.35	.236935	41
20	.764511	36.07	.999265	.13	.765246	36.18	.234754	40
21	8.766675	35.88	9.999257	.12	8.767417	36.02	11.232583	39
22	.768828	35.70	.999250	.13	.769578	35.82	.230422	38
23	.770970	35.52	.999242	.12	.771727	35.65	.228273	37
24	.773101	35.37	.999235	.13	.773866	35.48	.226134	36
25	.775223	35.17	.999227	.12	.775995	35.32	.224005	35
26	.777333	35.02	.999220	.13	.778114	35.13	.221886	34
27	.779434	34.83	.999212	.12	.780222	34.97	.219778	33
28	.781524	34.68	.999205	13	.782320	34.80	.217680	32
29	.783605	34.50	.999197	.13	.784408	34.63	.215592	31
30	.785675	34.35	.999189	.13	.786486	34.47	.213514	30
31	8.787736	34.18	9.999181	.12	8.788554	34.32	11.211446	29
32	.789787	34.02	.999174	.13	.790613	34.15	.209387	28
33	.791828	33.85	.999166	.13	.792662	33.98	.207338	27
34	.793859	33.70	.999158	.13	.794701	33.83	.205299	26
35	.795881	33.55	.999150	.13	.796731	33.68	.203269	25
36	.797894	33.38	.999142	.13	.798752	33.52	.201248	24
37	.799897	33.25	.999134	.13	.800763	33.37	.199237	23
38	.801892	33.07	.999126	.13	.802765	33.22	.197235	22
39	.803876	32.93	.999118	.13	.804758	33.07	.195242	21
40	.805852	32.78	.999110	.13	.806742	32.92	.193258	20
41	8.807819	32.63	9.999102	.13	8.808717	32.77	11.191283	19
42	.809777	32.48	.999094	.13	.810683	32.63	.189317	18
43	.811726	32.35	.999086	.15	.812641	32.47	.187359	17
44	.813667	32.20	.999077	.13	.814589	32.33	.185411	16
45	.815599	32.05	.999069	.13	.816529	32.20	.183471	15
46	.817522	31.90	.999061	.13	.818461	32.05	.181539	14
47	.819436	31.78	.999053	.15	.820384	31.90	.179616	13
48	.821343	31.62	.999044	.13	.822298	31.78	.177702	12
49	.823240	31.50	.999036	.15	.824205	31.63	.175795	11
50	.825130	31.35	.999027	.13	.826103	31.48	.173897	10
51	8.827011	31.22	9.999019	.15	8.827992	31.37	11.172008	9
52	.828884	31.08	.999010	.13	.829874	31.23	.170126	8
53	.830749	30.97	.999002	.15	.831748	31.08	.168252	7
54	.832607	30.82	.998993	.15	.833613	30.97	.166387	6
55	.834456	30.68	.998984	.13	.835471	30.83	.164529	5
56	.836297	30.55	.998976	.15	.837321	30.70	.162679	4
57	.838130	30.43	.998967	.15	.839163	30.58	.160837	3
58	.839956	30.30	.998958	.13	.840998	30.45	.159002	2
59	.841774	30.18	.998950	.15	.842825	30.32	.157175	1
60′	8.843585		9.998941		8.844614		11.155386	0
86°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	8

4°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	175°
0′	8.843585	30.08	9.998941	.15	8.844644	30.18	11.155356	60′
1	.845387	29.93	.998932	.15	.846455	30.08	.153545	59
2	.847183	29.80	.998923	.15	.848260	29.95	.151740	58
3	.848971	29.67	.998914	.15	.850057	29.82	.149943	57
4	.850751	29.57	.998905	.15	.851846	29.70	.148154	56
5	.852525	29.43	.998896	.15	.853628	29.58	.146372	55
6	.854291	29.30	.998887	.15	.855403	29.47	.144597	54
7	.856049	29.20	.998878	.15	.857171	29.35	.142829	53
8	.857801	29.08	.998869	.15	.858932	29.23	.141068	52
9	.859546	28.95	.998860	.15	.860686	29.12	.139314	51
10	.861283	28.85	.998851	.17	.862433	29.00	.137567	50
11	8.863014	28.73	9.998841	.15	8.864173	28.88	11.135827	49
12	.864738	28.62	.998832	.15	.865906	28.77	.134094	48
13	.866455	28.50	.998823	.17	.867632	28.65	.132368	47
14	.868165	28.38	.998813	.15	.869351	28.55	.130649	46
15	.869868	28.28	.998804	.15	.871064	28.43	.128936	45
16	.871565	28.17	.998795	.17	.872770	28.32	.127230	44
17	.873255	28.05	.998785	.15	.874469	28.22	.125531	43
18	.874938	27.95	.998776	.17	.876162	28.12	.123838	42
19	.876615	27.83	.998766	.15	.877849	28.00	.122151	41
20	.878285	27.73	.998757	.17	.879529	27.88	.120471	40
21	8.879949	27.63	9.998747	.15	8.881202	27.78	11.118798	39
22	.881607	27.52	.998738	.17	.882869	27.68	.117131	38
23	.883258	27.42	.998728	.17	.884530	27.58	.115470	37
24	.884903	27.32	.998718	.17	.886185	27.47	.113815	36
25	.886542	27.20	.998708	.15	.887833	27.38	.112167	35
26	.888174	27.12	.998699	.17	.889476	27.27	.110524	34
27	.889801	27.00	.998689	.17	.891112	27.17	.108888	33
28	.891421	26.90	.998679	.17	.892742	27.07	.107258	32
29	.893035	26.80	.998669	.17	.894366	26.97	.105634	31
30	.894643	26.72	.998659	.17	.895984	26.87	.104016	30
31	8.896246	26.60	9.998649	.17	8.897596	26.78	11.102404	29
32	.897842	26.50	.998639	.17	.899203	26.67	.100797	28
33	.899432	26.42	.998629	.17	.900803	26.58	.099197	27
34	.901017	26.32	.998619	.17	.902398	26.48	.097602	26
35	.902596	26.22	.998609	.17	.903987	26.38	.096013	25
36	.904169	26.12	.998599	.17	.905570	26.28	.094430	24
37	.905736	26.02	.998589	.18	.907147	26.20	.092853	23
38	.907297	25.93	.998578	.17	.908719	26.10	.091281	22
39	.908853	25.85	.998568	.17	.910285	26.02	.089715	21
40	.910404	25.75	.998558	.17	.911846	25.92	.088154	20
41	8.911949	25.65	9.998548	.18	8.913401	25.83	11.086599	19
42	.913488	25.57	.998537	.17	.914951	25.73	.085049	18
43	.915022	25.47	.998527	.18	.916495	25.65	.083505	17
44	.916550	25.38	.998516	.17	.918034	25.57	.081966	16
45	.918073	25.30	.998506	.18	.919568	25.47	.080432	15
46	.919591	25.20	.998495	.17	.921096	25.38	.078904	14
47	.921103	25.12	.998485	.18	.922619	25.28	.077381	13
48	.922610	25.03	.998474	.17	.924136	25.22	.075864	12
49	.924112	24.95	.998464	.18	.925649	25.12	.074351	11
50	.925609	24.85	.998453	.18	.927156	25.03	.072844	10
51	8.927100	24.78	9.998442	.18	8.928658	24.95	11.071342	9
52	.928587	24.68	.998431	.17	.930155	24.87	.069845	8
53	.930068	24.60	.998421	.18	.931647	24.78	.068353	7
54	.931544	24.52	.998410	.18	.933134	24.70	.066866	6
55	.933015	24.43	.998399	.18	.934616	24.62	.065384	5
56	.934481	24.35	.998388	.18	.936093	24.53	.063907	4
57	.935942	24.27	.998377	.18	.937565	24.45	.062435	3
58	.937398	24.20	.998366	.18	.939032	24.37	.060968	2
59	.938850	24.10	.998355	.18	.940494	24.30	.059506	1
60′	8.940296		9.998344		8.941952		11.058048	0′
°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

6°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	173°
0′	9.019235	20.00	9.997614	.22	9.021620	20.23	10.978380	60′
1	.020435	19.95	.997601	.22	.022834	20.17	.977166	59
2	.021632	19.88	.997588	.23	.024044	20.12	.975956	58
3	.022825	19.85	.997574	.22	.025251	20.07	.974749	57
4	.024016	19.78	.997561	.23	.026455	20.00	.973545	56
5	.025203	19.72	.997547	.22	.027655	19.95	.972345	55
6	.026386	19.68	.997534	.23	.028852	19.90	.971148	54
7	.027567	19.62	.997520	.22	.030046	19.85	.969954	53
8	.028744	19.57	.997507	.23	.031237	19.80	.968763	52
9	.029918	19.52	.997493	.22	.032425	19.73	.967575	51
10	.031089	19.47	.997480	.23	.033609	19.70	.966391	50
11	9.032257	19.40	9.997466	.23	9.034791	19.63	10.965209	49
12	.033421	19.35	.997452	.22	.035969	19.58	.964031	48
13	.034582	19.32	.997439	.23	.037144	19.53	.962856	47
14	.035741	19.25	.997425	.23	.038316	19.48	.961684	46
15	.036896	19.20	.997411	.23	.039485	19.43	.960515	45
16	.038048	19.15	.997397	.23	.040651	19.37	.959349	44
17	.039197	19.08	.997383	.23	.041813	19.33	.958187	43
18	.040342	19.05	.997369	.23	.042973	19.28	.957027	42
19	.041485	19.00	.997355	.23	.044130	19.23	.955870	41
20	.042625	18.95	.997341	.23	.045284	19.17	.954716	40
21	9.043762	18.88	9.997327	.23	9.046434	19.13	10.953566	39
22	.044895	18.85	.997313	.23	.047582	19.08	.952418	38
23	.046026	18.80	.997299	.23	.048727	19.03	.951273	37
24	.047154	18.75	.997285	.23	.049869	18.98	.950131	36
25	.048279	18.68	.997271	.23	.051008	18.93	.948992	35
26	.049400	18.65	.997257	.25	.052144	18.88	.947856	34
27	.050519	18.60	.997242	.23	.053277	18.83	.946723	33
28	.051635	18.57	.997228	.23	.054407	18.80	.945593	32
29	.052749	18.50	.997214	.25	.055535	18.73	.944465	31
30	.053859	18.45	.997199	.23	.056659	18.70	.943341	30
31	9.054966	18.42	9.997185	.25	9.057781	18.65	10.942219	29
32	.056071	18.35	.997170	.23	.058900	18.60	.941100	28
33	.057172	18.32	.997156	.25	.060016	18.57	.939984	27
34	.058271	18.27	.997141	.23	.061130	18.50	.938870	26
35	.059367	18.22	.997127	.25	.062240	18.47	.937760	25
36	.060460	18.18	.997112	.23	.063348	18.42	.936652	24
37	.061551	18.13	.997098	.25	.064453	18.38	.935547	23
38	.062639	18.08	.997083	.25	.065556	18.32	.934444	22
39	.063724	18.03	.997068	.25	.066655	18.28	.933345	21
40	.064806	17.98	.997053	.23	.067752	18.23	.932248	20
41	9.065885	17.95	9.997039	.25	9.068846	18.20	10.931154	19
42	.066962	17.90	.997024	.25	.069938	18.15	.930062	18
43	.068036	17.85	.997009	.25	.071027	18.10	.928973	17
44	.069107	17.82	.996994	.25	.072113	18.07	.927887	16
45	.070176	17.77	.996979	.25	.073197	18.02	.926803	15
46	.071242	17.73	.996964	.25	.074278	17.97	.925722	14
47	.072306	17.67	.996949	.25	.075356	17.93	.924644	13
48	.073366	17.63	.996934	.25	.076432	17.88	.923568	12
49	.074424	17.60	.996919	.25	.077505	17.85	.922495	11
50	.075480	17.55	.996904	.25	.078576	17.80	.921424	10
51	9.076533	17.50	9.996889	.25	9.079644	17.77	10.920356	9
52	.077583	17.47	.996874	.27	.080710	17.72	.919290	8
53	.078631	17.42	.996858	.25	.081773	17.67	.918227	7
54	.079676	17.38	.996843	.27	.082833	17.63	.917167	6
55	.080719	17.33	.996828	.27	.083891	17.60	.916109	5
56	.081759	17.30	.996812	.25	.084947	17.55	.915053	4
57	.082797	17.25	.996797	.25	.086000	17.50	.914000	3
58	.083832	17.20	.996782	.27	.087050	17.47	.912950	2
59	.084864	17.17	.996766	.25	.088098	17.43	.911902	1
60′	9.085894		9.996751		9.089144		10.910856	0′
	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	[illegible]

5°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	174°
0′	8.940296	24.03	9.998344	.18	8.941952	24.20	11.058048	60′
1	.941738	23.93	.998333	.18	.943404	24.13	.056596	59
2	.943174	23.87	.998322	.18	.944852	24.05	.055148	58
3	.944606	23.80	.998311	.18	.946295	23.98	.053705	57
4	.946034	23.70	.998300	.18	.947734	23.90	.052266	56
5	.947456	23.63	.998289	.20	.949168	23.82	.050832	55
6	.948874	23.55	.998277	.18	.950597	23 73	.049403	54
7	.950287	23.48	.998266	.18	.952021	23.67	.047979	53
8	.951696	23.40	.998255	.20	.953441	23.58	.046559	52
9	.953100	23.32	.998243	.18	.954856	23.52	.045144	51
10	.954499	23.25	.998232	.20	.956267	23.45	.043733	50
11	8.955894	23.17	9.998220	.18	8.957674	23.35	11.042326	49
12	.957284	23.10	.998209	.20	.959075	23.30	.040925	48
13	.958670	23.03	.998197	.18	.960473	23.22	.039527	47
14	.960052	22.95	.998186	.20	.961866	23.15	.038134	46
15	.961429	22.87	.998174	.18	.963255	23.07	.036745	45
16	.962801	22.82	.998163	.20	.964639	23.00	.035361	44
17	.964170	22.73	.998151	.20	.966019	22.92	.033981	43
18	.965534	22.65	.998139	.18	.967394	22.87	.032606	42
19	.966893	22.60	.998128	.20	.968766	22.78	.031234	41
20	.968249	22.52	.998116	.20	.970133	22.72	.029867	40
21	8.969600	22.45	9.998104	.20	8.971496	22.65	11.028504	39
22	.970947	22.37	.998092	.20	.972855	22.57	.027145	38
23	.972289	22.32	.998080	.20	.974209	22.52	.025791	37
24	.973628	22.23	.998068	.20	.975560	22.43	.024440	36
25	.974962	22.18	.998056	.20	.976906	22.37	.023094	35
26	.976293	22.10	.998044	.20	.978248	22.30	.021752	34
27	.977619	22.03	.998032	.20	.979586	22.25	.020414	33
28	.978941	21.97	.998020	.20	.980921	22.17	.019079	32
29	.980259	21.90	.998008	.20	.982251	22.10	.017749	31
30	.981573	21.83	.997996	.20	.983577	22.03	.016423	30
31	8.982883	21.77	9.997984	.20	8.984899	21.97	11.015101	29
32	.984189	21.70	.997972	.22	.986217	21.92	.013783	28
33	.985491	21.63	.997959	.20	.987532	21.83	.012468	27
34	.986789	21.57	.997947	.20	.988842	21.78	.011158	26
35	.988083	21.52	.997935	.22	.990149	21.70	.009851	25
36	.989374	21.43	.997922	.20	.991451	21.65	.008549	24
37	.990660	21.38	.997910	.22	.992750	21.58	.007250	23
38	.991943	21.32	.997897	.20	.994045	21.53	.005955	22
39	.993222	21.25	.997885	.22	.995337	21.45	.004663	21
40	.994497	21.18	.997872	.20	.996624	21.40	.003376	20
41	8.995768	21.13	9.997860	.22	8.997908	21.33	11.002092	19
42	.997036	21.05	.997847	.20	8.999188	21.28	11.000812	18
43	.998299	21.02	.997835	.22	9.000465	21.22	10.999535	17
44	8.999560	20.93	.997822	.22	.001738	21.15	.998262	16
45	9.000816	20.88	.997809	.20	.003007	21.08	.996993	15
46	.002069	20.82	.997797	.22	.004272	21.03	.995728	14
47	.003318	20.75	.997784	.22	.005534	20.97	.994466	13
48	.004563	20.70	.997771	.22	.006792	20.92	.993208	12
49	.005805	20.65	.997758	.22	.008047	20.85	.991953	11
50	.007044	20.57	.997745	.22	.009298	20.80	.990702	10
51	9.008278	20.53	9.997732	.22	9.010546	20.73	10.989454	9
52	.009510	20.45	.997719	.22	.011790	20.68	.988210	8
53	.010737	20.42	.997706	.22	.013031	20.62	.986969	7
54	.011962	20.33	.997693	.22	.014268	20.57	.985732	6
55	.013182	20.30	.997680	.22	.015502	20.50	.984498	5
56	.014400	20.22	.997667	.22	.016732	20.45	.983268	4
57	.015613	20.18	.997654	.22	.017959	20.40	.982041	3
58	.016824	20.12	.997641	.22	.019183	20.33	.980817	2
59	.018031	20.07	.997628	.23	.020403	20.28	.979597	1
60′	9.019235		9.997614		9.021620		10.978380	0′
95°	*Cosine.*	*D. 1".*	Sine.	D. 1".	Cotang.	D. 1".	Tang.	[illegible]

6°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	173°
0′	9.019235	20.00	9.997614	.22	9.021620	20.23	10.978380	60′
1	.020435	19.95	.997601	.22	.022834	20.17	.977166	59
2	.021632	19.88	.997588	.23	.024044	20.12	.975956	58
3	.022825	19.85	.997574	.22	.025251	20.07	.974749	57
4	.024016	19.78	.997561	.23	.026455	20.00	.973545	56
5	.025203	19.72	.997547	.22	.027655	19.95	.972345	55
6	.026386	19.68	.997534	.23	.028852	19.90	.971148	54
7	.027567	19.62	.997520	.22	.030046	19.85	.969954	53
8	.028744	19.57	.997507	.23	.031237	19.80	.968763	52
9	.029918	19.52	.997493	.22	.032425	19.73	.967575	51
10	.031089	19.47	.997480	.23	.033609	19.70	.966391	50
11	9.032257	19.40	9.997466	.23	9.034791	19.63	10.965209	49
12	.033421	19.35	.997452	.22	.035969	19.58	.964031	48
13	.034582	19.32	.997439	.23	.037144	19.53	.962856	47
14	.035741	19.25	.997425	.23	.038316	19.48	.961684	46
15	.036896	19.20	.997411	.23	.039485	19.43	.960515	45
16	.038048	19.15	.997397	.23	.040651	19.37	.959349	44
17	.039197	19.08	.997383	.23	.041813	19.33	.958187	43
18	.040342	19.05	.997369	.23	.042973	19.28	.957027	42
19	.041485	19.00	.997355	.23	.044130	19.23	.955870	41
20	.042625	18.95	.997341	.23	.045284	19.17	.954716	40
21	9.043762	18.88	9.997327	.23	9.046434	19.13	10.953566	39
22	.044895	18.85	.997313	.23	.047582	19.08	.952418	38
23	.046026	18.80	.997299	.23	.048727	19.03	.951273	37
24	.047154	18.75	.997285	.23	.049869	18.98	.950131	36
25	.048279	18.68	.997271	.23	.051008	18.93	.948992	35
26	.049400	18.65	.997257	.25	.052144	18.88	.947856	34
27	.050519	18.60	.997242	.23	.053277	18.83	.946723	33
28	.051635	18.57	.997228	.23	.054407	18.80	.945593	32
29	.052749	18.50	.997214	.25	.055535	18.78	.944465	31
30	.053859	18.45	.997199	.23	.056659	18.70	.943341	30
31	9.054966	18.42	9.997185	.25	9.057781	18.65	10.942219	29
32	.056071	18.35	.997170	.23	.058900	18.60	.941100	28
33	.057172	18.32	.997156	.25	.060016	18.57	.939984	27
34	.058271	18.27	.997141	.23	.061130	18.50	.938870	26
35	.059367	18.22	.997127	.25	.062240	18.47	.937760	25
36	.060460	18.18	.997112	.23	.063348	18.42	.936652	24
37	.061551	18.13	.997098	.25	.064453	18.38	.935547	23
38	.062639	18.08	.997083	.25	.065556	18.32	.934444	22
39	.063724	18.03	.997068	.25	.066655	18.28	.933345	21
40	.064806	17.98	.997053	.23	.067752	18.23	.932248	20
41	9.065885	17.95	9.997039	.25	9.068846	18.20	10.931154	19
42	.066962	17.90	.997024	.25	.069938	18.15	.930062	18
43	.068036	17.85	.997009	.25	.071027	18.10	.928973	17
44	.069107	17.82	.996994	.25	.072113	18.07	.927887	16
45	.070176	17.77	.996979	.25	.073197	18.02	.926803	15
46	.071242	17.73	.996964	.25	.074278	17.97	.925722	14
47	.072306	17.67	.996949	.25	.075356	17.93	.924644	13
48	.073366	17.63	.996934	.25	.076432	17.88	.923568	12
49	.074424	17.60	.996919	.25	.077505	17.85	.922495	11
50	.075480	17.55	.996904	.25	.078576	17.80	.921424	10
51	9.076533	17.50	9.996889	.25	9.079644	17.77	10.920356	9
52	.077583	17.47	.996874	.27	.080710	17.72	.919290	8
53	.078631	17.42	.996858	.25	.081773	17.67	.918227	7
54	.079676	17.38	.996843	.27	.082833	17.63	.917167	6
55	.080719	17.33	.996828	.27	.083891	17.60	.916109	5
56	.081759	17.30	.996812	.25	.084947	17.55	.915053	4
57	.082797	17.25	.996797	.25	.086000	17.50	.914000	3
	.083832	17.20	.996782	.27	.087050	17.47	.912950	2
	.084864	17.17	.996766	.25	.088098	17.43	.911902	1
	9.085894		9.996751		9.089144		10.910856	0
	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	83°

7°	Sine.	D. 1″.	Cosine.	D. 1″.	Tang.	D. 1″.	Cotang.	172°
0′	9.085894	17.13	9.996751	.27	9.089144	17.38	10.910856	60′
1	.086922	17.08	.996735	.25	.090187	17.35	.909813	59
2	.087947	17.05	.996720	.27	.091228	17.30	.908772	58
3	.088970	17.00	.996704	.27	.092266	17.27	.907734	57
4	.089990	16.97	.996688	.25	.093302	17.23	.906698	56
5	.091008	16.93	.996673	.27	.094336	17.18	.905664	55
6	.092024	16.88	.996657	.27	.095367	17.13	.904633	54
7	.093037	16.83	.996641	.27	.096395	17.12	.903605	53
8	.094047	16.82	.996625	.25	.097422	17.07	.902578	52
9	.095056	16.77	.996610	.27	.098446	17.03	.901554	51
10	.096062	16.72	.996594	.27	.099468	16.98	.900532	50
11	9.097065	16.68	9.996578	.27	9.100487	16.95	10.899513	49
12	.098066	16.65	.996562	.27	.101504	16.92	.898496	48
13	.099065	16.62	.996546	.27	.102519	16.88	.897481	47
14	.100062	16.57	.996530	.27	.103532	16.83	.896468	46
15	.101056	16.53	.996514	.27	.104542	16.80	.895458	45
16	.102048	16.48	.996498	.27	.105550	16.77	.894450	44
17	.103037	16.47	.996482	.28	.106556	16.72	.893444	43
18	.104025	16.42	.996465	.27	.107559	16.68	.892441	42
19	.105010	16.37	.996449	.27	.108560	16.65	.891440	41
20	.105992	16.35	.996433	.27	.109559	16.62	.890441	40
21	9.106973	16.30	9.996417	.28	9.110556	16.58	10.889444	39
22	.107951	16.27	.996400	.27	.111551	16.53	.888449	38
23	.108927	16.23	.996384	.27	.112543	16.50	.887457	37
24	.109901	16.20	.996368	.28	.113533	16.47	.886467	36
25	.110873	16.15	.996351	.27	.114521	16.43	.885479	35
26	.111842	16.12	.996335	.28	.115507	16.40	.884493	34
27	.112809	16.08	.996318	.27	.116491	16.35	.883509	33
28	.113774	16.05	.996302	.28	.117472	16.33	.882528	32
29	.114737	16.02	.996285	.27	.118452	16.28	.881548	31
30	.115698	15.97	.996269	.28	.119429	16.25	.880571	30
31	9.116656	15.95	9.996252	.28	9.120404	16.22	10.879596	29
32	.117613	15.90	.996235	.27	.121377	16.18	.878623	28
33	.118567	15.87	.996219	.28	.122348	16.15	.877652	27
34	.119519	15.83	.996202	.28	.123317	16.12	.876683	26
35	.120469	15.80	.996185	.28	.124284	16.08	.875716	25
36	.121417	15.75	.996168	.28	.125249	16.03	.874751	24
37	.122362	15.73	.996151	.28	.126211	16.02	.873789	23
38	.123306	15.70	.996134	.28	.127172	15.97	.872828	22
39	.124248	15.65	.996117	.28	.128130	15.95	.871870	21
40	.125187	15.63	.996100	.28	.129087	15.90	.870913	20
41	9.126125	15.58	9.996083	.28	9.130041	15.88	10.869959	19
42	.127060	15.55	.996066	.28	.130994	15.83	.869006	18
43	.127993	15.53	.996049	.28	.131944	15.82	.868056	17
44	.128925	15.48	.996032	.28	.132893	15.77	.867107	16
45	.129854	15.45	.996015	.28	.133839	15.75	.866161	15
46	.130781	15.42	.995998	.30	.134784	15.70	.865216	14
47	.131706	15.40	.995980	.28	.135726	15.68	.864274	13
48	.132630	15.35	.995963	.28	.136667	15.63	.863333	12
49	.133551	15.32	.995946	.30	.137605	15.62	.862395	11
50	.134470	15.28	.995928	.28	.138542	15.57	.861458	10
51	9.135387	15.27	9.995911	.28	9.139476	15.55	10.860524	9
52	.136303	15.22	.995894	.30	.140409	15.52	.859591	8
53	.137216	15.20	.995876	.28	.141340	15.48	.858660	7
54	.138128	15.15	.995859	.30	.142269	15.45	.857731	6
55	.139037	15.12	.995841	.30	.143196	15.42	.856804	5
56	.139944	15.10	.995823	.28	.144121	15.38	.855879	4
57	.140850	15.07	.995806	.30	.145044	15.37	.854956	3
58	.141754	15.02	.995788	.28	.145966	15.32	.854034	2
59	.142655	15.00	.995771	.30	.146885	15.30	.853115	1
60′	9.143555		9.995753		9.147803		10.852197	0
97°	*Cosine.*	*D. 1″.*	Sine.	D. 1″.	Cotang.	D. 1″.	Tang.	8

8°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	171°
0′	9.143555	14.97	9.995753	.30	9.147803	15.25	10.852197	60′
1	.144453	14.93	.995735	.30	.148718	15.23	.851282	59
2	.145349	14.90	.995717	.30	.149632	15.20	.850368	58
3	.146243	14.88	.995699	.30	.150544	15.17	.849456	57
4	.147136	14.83	.995681	.28	.151454	15.15	.848546	56
5	.148026	14.82	.995664	.30	.152363	15.10	.847637	55
6	.148915	14.78	.995646	.30	.153269	15.08	.846731	54
7	.149802	14.73	.995628	.30	.154174	15.05	.845826	53
8	.150686	14.72	.995610	.32	.155077	15.02	.844923	52
9	.151569	14.70	.995591	.30	.155978	14.98	.844022	51
10	.152451	14.65	.995573	.30	.156877	14.97	.843123	50
11	9.153330	14.63	9.995555	.30	9.157775	14.93	10.842225	49
12	.154208	14.58	.995537	.30	.158671	14.90	.841329	48
13	.155083	14.57	.995519	.30	.159565	14.87	.840435	47
14	.155957	14.55	.995501	.32	.160457	14.83	.839543	46
15	.156830	14.50	.995482	.30	.161347	14.82	.838653	45
16	.157700	14.48	.995464	.30	.162236	14.78	.837764	44
17	.158569	14.43	.995446	.32	.163123	14.75	.836877	43
18	.159435	14.43	.995427	.30	.164008	14.73	.835992	42
19	.160301	14.38	.995409	.32	.164892	14.70	.835108	41
20	.161164	14.35	.995390	.30	.165774	14.67	.834226	40
21	9.162025	14.33	9.995372	.32	9.166654	14.63	10.833346	39
22	.162885	14.30	.995353	.32	.167532	14.62	.832468	38
23	.163743	14.28	.995334	.30	.168409	14.58	.831591	37
24	.164600	14.23	.995316	.32	.169284	14.55	.830716	36
25	.165454	14.22	.995297	.32	.170157	14.53	.829843	35
26	.166307	14.20	.995278	.30	.171029	14.50	.828971	34
27	.167159	14.15	.995260	.32	.171899	14.47	.828101	33
28	.168008	14.13	.995241	.32	.172767	14.45	.827233	32
29	.168856	14.10	.995222	.32	.173634	14.42	.826366	31
30	.169702	14.08	.995203	.32	.174499	14.38	.825501	30
31	9.170547	14.03	9.995184	.32	9.175362	14.37	10.824638	29
32	.171389	14.02	.995165	.32	.176224	14.33	.823776	28
33	.172230	14.00	.995146	.32	.177084	14.30	.822916	27
34	.173070	13.97	.995127	.32	.177942	14.28	.822058	26
35	.173908	13.93	.995108	.32	.178799	14.27	.821201	25
36	.174744	13.90	.995089	.32	.179655	14.22	.820345	24
37	.175578	13.88	.995070	.32	.180508	14.20	.819492	23
38	.176411	13.85	.995051	.32	.181360	14.18	.818640	22
39	.177242	13.83	.995032	.32	.182211	14.13	.817789	21
40	.178072	13.80	.995013	.33	.183059	14.13	.816941	20
41	9.178900	13.77	9.994993	.32	9.183907	14.08	10.816093	19
42	.179726	13.75	.994974	.32	.184752	14.08	.815248	18
43	.180551	13.72	.994955	.33	.185597	14.03	.814403	17
44	.181374	13.70	.994935	.32	.186439	14.02	.813561	16
45	.182196	13.67	.994916	.33	.187280	14.00	.812720	15
46	.183016	13.63	.994896	.32	.188120	13.97	.811880	14
47	.183834	13.62	.994877	.33	.188958	13.93	.811042	13
48	.184651	13.58	.994857	.32	.189794	13.92	.810206	12
49	.185466	13.57	.994838	.33	.190629	13.88	.809371	11
50	.186280	13.53	.994818	.33	.191462	13.87	.808538	10
51	9.187092	13.52	9.994798	.32	9.192294	13.83	10.807706	9
52	.187903	13.48	.994779	.33	.193124	13.82	.806876	8
53	.188712	13.45	.994759	.33	.193953	13.78	.806047	7
54	.189519	13.43	.994739	.32	.194780	13.77	.805220	6
55	.190325	13.42	.994720	.33	.195606	13.73	.804394	5
56	.191130	13.38	.994700	.33	.196430	13.72	.803570	4
57	.191933	13.35	.994680	.33	.197253	13.68	.802747	3
58	.192734	13.33	.994660	.33	.198074	13.67	.801926	2
59	.193534	13.30	.994640	.33	.198894	13.65	.801106	1
60′	9.194332		9.994620		9.199713		10.800287	0
98°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	81°

9°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	170°
0′	9.194332	13.28	9.994620	.33	9.199713	13.60	10.800287	60′
1	.195129	13.27	.994600	.33	.200529	13.60	.799471	59
2	.195925	13.23	.994580	.33	.201345	13.57	.798655	58
3	.196719	13.20	.994560	.33	.202159	13.53	.797841	57
4	.197511	13.18	.994540	.35	.202971	13.52	.797029	56
5	.198302	13.15	.994519	.33	.203782	13.50	.796218	55
6	.199091	13.13	.994499	.33	.204592	13.47	.795408	54
7	.199879	13.12	.994479	.33	.205400	13.45	.794600	53
8	.200666	13.08	.994459	.35	.206207	13.43	.793793	52
9	.201451	13.05	.994438	.33	.207013	13.40	.792987	51
10	.202234	13.05	.994418	.33	.207817	13.37	.792183	50
11	9.203017	13.00	9.994398	.35	9.208619	13.35	10.791381	49
12	.203797	13.00	.994377	.33	.209420	13.33	.790580	48
13	.204577	12.95	.994357	.35	.210220	13.30	.789780	47
14	.205354	12.95	.994336	.33	.211018	13.28	.788982	46
15	.206131	12.92	.994316	.35	.211815	13.27	.788185	45
16	.206906	12.88	.994295	.35	.212611	13.23	.787389	44
17	.207679	12.88	.994274	.33	.213405	13.22	.786595	43
18	.208452	12.83	.994254	.35	.214198	13.18	.785802	42
19	.209222	12.83	.994233	.35	.214989	13.18	.785011	41
20	.209992	12.80	.994212	.35	.215780	13.13	.784220	40
21	9.210760	12.77	9.994191	.33	9.216568	13.13	10.783432	39
22	.211526	12.75	.994171	.35	.217356	13.10	.782644	38
23	.212291	12.73	.994150	.35	.218142	13.07	.781858	37
24	.213055	12.72	.994129	.35	.218926	13.07	.781074	36
25	.213818	12.68	.994108	.35	.219710	13.03	.780290	35
26	.214579	12.65	.994087	.35	.220492	13.00	.779508	34
27	.215338	12.65	.994066	.35	.221272	13.00	.778728	33
28	.216097	12.62	.994045	.35	.222052	12.97	.777948	32
29	.216854	12.58	.994024	.35	.222830	12.95	.777170	31
30	.217609	12.57	.994003	.35	.223607	12.92	.776393	30
31	9.218363	12.55	9.993982	.37	9.224382	12.90	10.775618	29
32	.219116	12.53	.993960	.35	.225156	12.88	.774844	28
33	.219868	12.50	.993939	.35	.225929	12.85	.774071	27
34	.220618	12.48	.993918	.35	.226700	12.85	.773300	26
35	.221367	12.47	.993897	.37	.227471	12.80	.772529	25
36	.222115	12.43	.993875	.35	.228239	12.80	.771761	24
37	.222861	12.42	.993854	.37	.229007	12.77	.770993	23
38	.223606	12.38	.993832	.35	.229773	12.77	.770227	22
39	.224349	12.38	.993811	.37	.230539	12.72	.769461	21
40	.225092	12.35	.993789	.35	.231302	12.72	.768698	20
41	9.225833	12.33	9.993768	.37	9.232065	12.68	10.767935	19
42	.226573	12.30	.993746	.35	.232826	12.67	.767174	18
43	.227311	12.28	.993725	.37	.233586	12.65	.766414	17
44	.228048	12.27	.993703	.37	.234345	12.63	.765655	16
45	.228784	12.23	.993681	.35	.235103	12.60	.764897	15
46	.229518	12.23	.993660	.37	.235859	12.58	.764141	14
47	.230252	12.20	.993638	.37	.236614	12.57	.763386	13
48	.230984	12.18	.993616	.37	.237368	12.53	.762632	12
49	.231715	12.15	.993594	.37	.238120	12.53	.761880	11
50	.232444	12.13	.993572	.37	.238872	12.50	.761128	10
51	9.233172	12.12	9.993550	.37	9.239622	12.48	10.760378	9
52	.233899	12.10	.993528	.37	.240371	12.45	.759629	8
53	.234625	12.07	.993506	.37	.241118	12.45	.758882	7
54	.235349	12.07	.993484	.37	.241865	12.42	.758135	6
55	.236073	12.03	.993462	.37	.242610	12.40	.757390	5
56	.236795	12.00	.993440	.37	.243354	12.38	.756646	4
57	.237515	12.00	.993418	.37	.244097	12.37	.755903	3
58	.238235	11.97	.993396	.37	.244839	12.33	.755161	2
59	.238953	11.95	.993374	.38	.245579	12.33	.754421	1
60′	9.239670		9.993351		9.246319		10.753681	0′
99°	*Cosine.*	*D. 1".*	Sine.	D. 1".	Cotang.	D. 1".	Tang.	80°

10°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	169°
0'	9.239670	11.93	9.993351	.37	9.246319	12.30	10.753681	60'
1	.240386	11.92	.993329	.37	.247057	12.28	.752943	59
2	.241101	11.88	.993307	.38	.247794	12.27	.752206	58
3	.241814	11.87	.993284	.37	.248530	12.23	.751470	57
4	.242526	11.85	.993262	.37	.249264	12.23	.750736	56
5	.243237	11.83	.993240	.38	.249998	12.20	.750002	55
6	.243947	11.82	.993217	.37	.250730	12.18	.749270	54
7	.244656	11.78	.993195	.38	.251461	12.17	.748539	53
8	.245363	11.77	.993172	.38	.252191	12.15	.747809	52
9	.246069	11.77	.993149	.37	.252920	12.13	.747080	51
10	.246775	11.72	.993127	.38	.253648	12.10	.746352	50
11	9.247478	11.72	9.993104	.38	9.254374	12.10	10.745626	49
12	.248181	11.70	.993081	.37	.255100	12.07	.744900	48
13	.248883	11.67	.993059	.38	.255824	12.05	.744176	47
14	.249583	11.65	.993036	.38	.256547	12.03	.743453	46
15	.250282	11.63	.993013	.38	.257269	12.02	.742731	45
16	.250980	11.62	.992990	.38	.257990	12.00	.742010	44
17	.251677	11.60	.992967	.38	.258710	11.98	.741290	43
18	.252373	11.57	.992944	.38	.259429	11.95	.740571	42
19	.253067	11.57	.992921	.38	.260146	11.95	.739854	41
20	.253761	11.53	.992898	.38	.260863	11.92	.739137	40
21	9.254453	11.52	9.992875	.38	9.261578	11.90	10.738422	39
22	.255144	11.50	.992852	.38	.262292	11.88	.737708	38
23	.255834	11.48	.992829	.38	.263005	11.87	.736995	37
24	.256523	11.47	.992806	.38	.263717	11.85	.736283	36
25	.257211	11.45	.992783	.40	.264428	11.83	.735572	35
26	.257898	11.42	.992759	.38	.265138	11.82	.734862	34
27	.258583	11.42	.992736	.38	.265847	11.80	.734153	33
28	.259268	11.38	.992713	.38	.266555	11.77	.733445	32
29	.259951	11.37	.992690	.40	.267261	11.77	.732739	31
30	.260633	11.35	.992666	.38	.267967	11.73	.732033	30
31	9.261314	11.33	9.992643	.40	9.268671	11.73	10.731329	29
32	.261994	11.32	.992619	.38	.269375	11.70	.730625	28
33	.262673	11.30	.992596	.40	.270077	11.70	.729923	27
34	.263351	11.27	.992572	.38	.270779	11.67	.729221	26
35	.264027	11.27	.992549	.40	.271479	11.65	.728521	25
36	.264703	11.23	.992525	.40	.272178	11.63	.727822	24
37	.265377	11.23	.992501	.38	.272876	11.62	.727124	23
38	.266051	11.20	.992478	.40	.273573	11.60	.726427	22
39	.266723	11.20	.992454	.40	.274269	11.58	.725731	21
40	.267395	11.17	.992430	.40	.274964	11.57	.725036	20
41	9.268065	11.15	9.992406	.40	9.275658	11.55	10.724342	19
42	.268734	11.13	.992382	.38	.276351	11.53	.723649	18
43	.269402	11.12	.992359	.40	.277043	11.52	.722957	17
44	.270069	11.10	.992335	.40	.277734	11.50	.722266	16
45	.270735	11.08	.992311	.40	.278424	11.48	.721576	15
46	.271400	11.07	.992287	.40	.279113	11.47	.720887	14
47	.272064	11.03	.992263	.40	.279801	11.45	.720199	13
48	.272726	11.03	.992239	.42	.280488	11.43	.719512	12
49	.273388	11.02	.992214	.40	.281174	11.40	.718826	11
50	.274049	10 98	.992190	.40	.281858	11.40	.718142	10
51	9.274708	10.98	9.992166	.40	9.282542	11.38	10.717458	9
52	.275367	10.97	.992142	.40	.283225	11.37	.716775	8
53	.276025	10.93	.992118	.42	.283907	11.35	.716093	7
54	.276681	10.93	.992093	.40	.284588	11.33	.715412	6
55	.277337	10.90	.992069	.42	.285268	11.32	.714732	5
56	.277991	10.90	.992044	.40	.285947	11.28	.714053	4
57	.278645	10.87	.992020	.40	.286624	11.28	.713376	3
	.279297	10.85	.991996	.42	.287301	11.27	.712699	2
	.279948	10.85	.991971	.40	.287977	11.25	.712023	1
	9.280599		9.991947		9.288652		10.711348	0
		D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	168°
9.280599	10.82	9.991947	.42	9.288652	11.23	10.711348	60′
.281248	10.82	.991922	.42	.289326	11.22	.710674	59
.281897	10.78	.991897	.40	.289999	11.20	.710001	58
.282544	10.77	.991873	.42	.290671	11.18	.709329	57
.283190	10.77	.991848	.42	.291342	11.18	.708658	56
.283836	10.73	.991823	.40	.292013	11.15	.707987	55
.284480	10.73	.991799	.42	.292682	11.13	.707318	54
.285124	10.70	.991774	.42	.293350	11.12	.706650	53
.285766	10.70	.991749	.42	.294017	11.12	.705983	52
.286408	10.67	.991724	.42	.294684	11.08	.705316	51
.287048	10.67	.991699	.42	.295349	11.07	.704651	50
9.287688	10.63	9.991674	.42	9.296013	11.07	10.703987	49
.288326	10.63	.991649	.42	.296677	11.03	.703323	48
.288964	10.60	.991624	.42	.297339	11.03	.702661	47
.289600	10.60	.991599	.42	.298001	11.02	.701999	46
.290236	10.57	.991574	.42	.298662	11.00	.701338	45
.290870	10.57	.991549	.42	.299322	10.97	.700678	44
.291504	10.55	.991524	.43	.299980	10.97	.700020	43
.292137	10.52	.991498	.42	.300638	10.95	.699362	42
.292768	10.52	.991473	.42	.301295	10.93	.698705	41
.293399	10.50	.991448	.43	.301951	10.93	.698049	40
9.294029	10.48	9.991422	.42	9.302607	10.90	10.697393	39
.294658	10.47	.991397	.42	.303261	10.88	.696739	38
.295286	10.45	.991372	.43	.303914	10.88	.696086	37
.295913	10.43	.991346	.42	.304567	10.85	.695433	36
.296539	10.42	.991321	.43	.305218	10.85	.694782	35
.297164	10.40	.991295	.42	.305869	10.83	.694131	34
.297788	10.40	.991270	.43	.306519	10.82	.693481	33
.298412	10.37	.991244	.43	.307168	10.80	.692832	32
.299034	10.35	.991218	.42	.307816	10.78	.692184	31
.299655	10.35	.991193	.43	.308463	10.77	.691537	30
9.300276	10.32	9.991167	.43	9.309100	10.75	10.690891	29
.300895	10.32	.991141	.43	.309754	10.75	.690246	28
.301514	10.30	.991115	.42	.310399	10.72	.689601	27
.302132	10.27	.991090	.43	.311042	10.72	.688958	26
.302748	10.27	.991064	.43	.311685	10.70	.688315	25
.303364	10.25	.991038	.43	.312327	10.68	.687673	24
.303979	10.23	.991012	.43	.312968	10.67	.687032	23
.304593	10.23	.990986	.43	.313608	10.65	.686392	22
.305207	10.20	.990960	.43	.314247	10.63	.685753	21
.305819	10.18	.990934	.43	.314885	10.63	.685115	20
9.306430	10.18	9.990908	.43	9.315523	10.60	10.684477	19
.307041	10.15	.990882	.45	.316159	10.60	.683841	18
.307650	10.15	.990855	.43	.316795	10.58	.683205	17
.308259	10.13	.990829	.43	.317430	10.57	.682570	16
.308867	10.12	.990803	.43	.318064	10.55	.681936	15
.309474	10.10	.990777	.45	.318697	10.55	.681303	14
.310080	10.08	.990750	.43	319330	10.52	.680670	13
.310685	10.07	.990724	.45	.319961	10.52	.680039	12
.311289	10.07	.990697	.43	.320592	10.50	.679408	11
.311893	10.03	.990671	.43	.321222	10.48	.678778	10
9.312495	10.03	9.990645	.45	9.321851	10.47	10.678149	9
.313097	10.02	.990618	.45	.322479	10.45	.677521	8
.313698	9.98	.990591	.43	.323106	10.45	.676894	7
.314297	10.00	.990565	.45	.323733	10.42	.676267	6
.314897	9.97	.990538	.45	.324358	10.42	.675642	5
.315495	9.95	.990511	.43	.324983	10.40	.675017	4
.316092	9.95	.990485	.45	.325607	10.40	.674393	3
.316689	9.92	.990458	.45	.326231	10.37	.673769	2
.317284	9.92	.990431	.45	.326853	10.37	.673147	1
9.317879		9.990404		9.327475		10.672525	0′
° *Cosine.*	*D. 1".*	Sine.	D. 1".	Cotang.	D. 1".	Tang.	78°

12°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	167°
0′	9.317879	9.90	9.990404	.43	9.327475	10.33	10.672525	60′
1	.318473	9.88	.990378	.45	.328095	10.33	.671905	59
2	.319066	9.87	.990351	.45	.328715	10.32	.671285	58
3	.319658	9.85	.990324	.45	.329334	10.32	.670666	57
4	.320249	9.85	.990297	.45	.329953	10.28	.670047	56
5	.320840	9.83	.990270	.45	.330570	10.28	.669430	55
6	.321430	9.82	.990243	.47	.331187	10.27	.668813	54
7	.322019	9.80	.990215	.45	.331803	10.25	.668197	53
8	.322607	9.78	.990188	.45	.332418	10.25	.667582	52
9	.323194	9.77	.990161	.45	.333033	10.22	.666967	51
10	.323780	9.77	.990134	.45	.333646	10.22	.666354	50
11	9.324366	9.73	9.990107	.47	9.334259	10.20	10.665741	49
12	.324950	9.73	.990079	.45	.334871	10.18	.665129	48
13	.325534	9.72	.990052	.45	.335482	10.18	.664518	47
14	.326117	9.72	.990025	.47	.336093	10.15	.663907	46
15	.326700	9.68	.989997	.45	.336702	10.15	.663298	45
16	.327281	9.68	.989970	.47	.337311	10.13	.662689	44
17	.327862	9.67	.989942	.45	.337919	10.13	.662081	43
18	.328442	9.65	.989915	.47	.338527	10.10	.661473	42
19	.329021	9.63	.989887	.45	.339133	10.10	.660867	41
20	.329599	9.62	.989860	.47	.339739	10.08	.660261	40
21	9.330176	9.62	9.989832	.47	9.340344	10.07	10.659656	39
22	.330753	9.60	.989804	.45	.340948	10.07	.659052	38
23	.331329	9.57	.989777	.47	.341552	10.05	.658448	37
24	.331903	9.58	.989749	.47	.342155	10.03	.657845	36
25	.332478	9.55	.989721	.47	.342757	10.02	.657243	35
26	.333051	9.55	.989693	.47	.343358	10.00	.656642	34
27	.333624	9.52	.989665	.47	.343958	10.00	.656042	33
28	.334195	9.53	.989637	.45	.344558	9.98	.655442	32
29	.334767	9.50	.989610	.47	.345157	9.97	.654843	31
30	.335337	9.48	.989582	.48	.345755	9.97	.654245	30
31	9.335906	9.48	9.989553	.47	9.346353	9.93	10.653647	29
32	.336475	9.47	.989525	.47	.346949	9.93	.653051	28
33	.337043	9.45	.989497	.47	.347545	9.93	.652455	27
34	.337610	9.43	.989469	.47	.348141	9.90	.651859	26
35	.338176	9.43	.989441	.47	.348735	9.90	.651265	25
36	.338742	9.42	.989413	.47	.349329	9.88	.650671	24
37	.339307	9.40	.989385	.48	.349922	9.87	.650078	23
38	.339871	9.38	.989356	.47	.350514	9.87	.649486	22
39	.340434	9.37	.989328	.47	.351106	9.85	.648894	21
40	.340996	9.37	.989300	.48	.351697	9.83	.648303	20
41	9.341558	9.35	9.989271	.47	9.352287	9.82	10.647713	19
42	.342119	9.33	.989243	.48	.352876	9.82	.647124	18
43	.342679	9.33	.989214	.47	.353465	9.80	.646535	17
44	.343239	9.30	.989186	.48	.354053	9.78	.645947	16
45	.343797	9.30	.989157	.48	.354640	9.78	.645360	15
46	.344355	9.28	.989128	.47	.355227	9.77	.644773	14
47	.344912	9.28	.989100	.48	.355813	9.75	.644187	13
48	.345469	9.25	.989071	.48	.356398	9.73	.643602	12
49	.346024	9.25	.989042	.47	.356982	9.73	.643018	11
50	.346579	9.25	.989014	.48	.357566	9.72	.642434	10
51	9.347134	9.22	9.988985	.48	9.358149	9.70	10.641851	9
52	.347687	9.22	.988956	.48	.358731	9.70	.641269	8
53	.348240	9.20	.988927	.48	.359313	9.67	.640687	7
54	.348792	9.18	.988898	.48	.359893	9.68	.640107	6
55	.349343	9.17	.988869	.48	.360474	9.65	.639526	5
56	.349893	9.17	.988840	.48	.361053	9.65	.638947	4
57	.350443	9.15	.988811	.48	.361632	9.63	.638368	3
58	.350992	9.13	.988782	.48	.362210	9.62	.637790	2
59	.351540	9.13	.988753	.48	.362787	9.62	.637213	1
60′	9.352088		9.988724		9.363364		10.636636	0′
102°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

Sine.	D. 1″.	Cosine.	D. 1″.	Tang.	D. 1″.	Cotang.	166°
9.352088	9.12	9.988724	.48	9.363364	9.60	10.636636	60′
.352635	9.10	.988695	.48	.363940	9.58	.636060	59
.353181	9.08	.988666	.50	.364515	9.58	.635485	58
.353726	9.08	.988636	.48	.365090	9.57	.634910	57
.354271	9.07	.988607	.48	.365664	9.55	.634336	56
.354815	9.05	.988578	.50	.366237	9.55	.633763	55
.355358	9.05	.988548	.48	.366810	9.53	.633190	54
.355901	9.03	.988519	.50	.367382	9.52	.632618	53
.356443	9.02	.988489	.48	.367953	9.52	.632047	52
.356984	9.00	.988460	.50	.368524	9.50	.631476	51
.357524	9.00	.988430	.48	.369094	9.48	.630906	50
9.358064	8.98	9.988401	.50	9.369663	9.48	10.630337	49
.358603	8.97	.988371	.48	.370232	9.45	.629768	48
.359141	8.95	.988342	.50	.370799	9.47	.629201	47
.359678	8.95	.988312	.50	.371367	9.43	.628633	46
.360215	8.95	.988282	.50	.371933	9.43	.628067	45
.360752	8.92	.988252	.48	.372499	9.42	.627501	44
.361287	8.92	.988223	.50	.373064	9.42	.626936	43
.361822	8.90	.988193	.50	.373629	9.40	.626371	42
.362356	8.88	.988163	.50	.374193	9.38	.625807	41
.362889	8.88	.988133	.50	.374756	9.38	.625244	40
9.363422	8.87	9.988103	.50	9.375319	9.37	10.624681	39
.363954	8.85	.988073	.50	.375881	9.35	.624119	38
.364485	8.85	.988043	.50	.376442	9.35	.623558	37
.365016	8.83	.988013	.50	.377003	9.33	.622997	36
.365546	8.82	.987983	.50	.377563	9.32	.622437	35
.366075	8.82	.987953	.52	.378122	9.32	.621878	34
.366604	8.78	.987922	.50	.378681	9.30	.621319	33
.367131	8.80	.987892	.50	.379239	9.30	.620761	32
.367659	8.77	.987862	.50	.379797	9.28	.620203	31
.368185	8.77	.987832	.52	.380354	9.27	.619646	30
9.368711	8.75	9.987801	.50	9.380910	9.27	10.619090	29
.369236	8.75	.987771	.52	.381466	9.23	.618534	28
.369761	8.72	.987740	.50	.382020	9.25	.617980	27
.370285	8.72	.987710	.52	.382575	9.23	.617425	26
.370808	8.70	.987679	.50	.383129	9.22	.616871	25
.371330	8.70	.987649	.52	.383682	9.20	.616318	24
.371852	8.68	.987618	.50	.384234	9.20	.615766	23
.372373	8.68	.987588	.52	.384786	9.18	.615214	22
.372894	8.67	.987557	.52	.385337	9.18	.614663	21
.373414	8.65	.987526	.50	.385888	9.17	.614112	20
9.373933	8.65	9.987496	.52	9.386438	9.15	10.613562	19
.374452	8.63	.987465	.52	.386987	9.15	.613013	18
.374970	8.62	.987434	.52	.387536	9.13	.612464	17
.375487	8.60	.987403	.52	.388084	9.12	.611916	16
.376003	8.60	.987372	.52	.388631	9.12	.611369	15
.376519	8.60	.987341	.52	.389178	9.10	.610822	14
.377035	8.57	.987310	.52	.389724	9.10	.610276	13
.377549	8.57	.987279	.52	.390270	9.08	.609730	12
.378063	8.57	.987248	.52	.390815	9.08	.609185	11
.378577	8.53	.987217	.52	.391360	9.05	.608640	10
9.379089	8.53	9.987186	.52	9.391903	9.07	10.608097	9
.379601	8.53	.987155	.52	.392447	9.03	.607553	8
.380113	8.52	.987124	.53	.392989	9.03	.607011	7
.380624	8.50	.987092	.52	.393531	9.03	.606469	6
.381134	8.48	.987061	.52	.394073	9.02	.605927	5
.381643	8.48	.987030	.53	.394614	9.00	.605386	4
.382152	8.48	.986998	.52	.395154	9.00	.604846	3
.382661	8.45	.986967	.52	.395694	8.98	.604306	2
.383168	8.45	.986936	.53	.396233	8.97	.603767	1
9.383675		9.986904		9.396771		10.603229	0
° *Cosine.*	*D. 1″.*	Sine.	D. 1″.	Cotang.	D. 1″.	Tang.	76°

14°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.
0′	9.383675	8.45	9.986904	.52	9.396771	8.97	10.60322
1	.384182	8.42	.986873	.53	.397309	8.95	.60269
2	.384687	8.42	.986841	.53	.397846	8.95	.60215
3	.385192	8.42	.986809	.52	.398383	8.93	.60161
4	.385697	8.40	.986778	.53	.398919	8.93	.60108
5	.386201	8.38	.986746	.53	.399455	8.92	.60054
6	.386704	8.38	.986714	.52	.399990	8.90	.60001
7	.387207	8.37	.986683	.53	.400524	8.90	.59947
8	.387709	8.35	.986651	.53	.401058	8.88	.59894
9	.388210	8.35	.986619	.53	.401591	8.88	.59840
10	.388711	8.33	.986587	.53	.402124	8.87	.59787
11	9.389211	8.33	9.986555	.53	9.402656	8.85	10.59734
12	.389711	8.32	.986523	.53	.403187	8.85	.59681
13	.390210	8.30	.986491	.53	.403718	8.85	.59628
14	.390708	8.30	.986459	.53	.404249	8.82	.595751
15	.391206	8.28	.986427	.53	.404778	8.83	.59522
16	.391703	8.27	.986395	.53	.405308	8.80	.59469
17	.392199	8.27	.986363	.53	.405836	8.80	.59416
18	.392695	8.27	.986331	.53	.406364	8.80	.59363
19	.393191	8.23	.986299	.55	.406892	8.78	.59310
20	.393685	8.23	.986266	.53	.407419	8.77	.592581
21	9.394179	8.23	9.986234	.53	9.407945	8.77	10.59205
22	.394673	8.22	.986202	.55	.408471	8.75	.59152
23	.395166	8.20	.986169	.53	.408996	8.75	.591004
24	.395658	8.20	.986137	.55	.409521	8.73	.590479
25	.396150	8.18	.986104	.53	.410045	8.73	.589955
26	.396641	8.18	.986072	.55	.410569	8.72	.589431
27	.397132	8.15	.986039	.53	.411092	8.72	.588908
28	.397621	8.17	.986007	.55	.411615	8.70	.588385
29	.398111	8.15	.985974	.53	.412137	8.68	.587863
30	.398600	8.13	.985942	.55	.412658	8.68	.587342
31	9.399088	8.12	9.985909	.55	9.413179	8.67	10.586821
32	.399575	8.12	.985876	.55	.413699	8.67	.586301
33	.400062	8.12	.985843	.53	.414219	8.65	.585781
34	.400549	8.10	.985811	.55	.414738	8.65	.585262
35	.401035	8.08	.985778	.55	.415257	8.63	.584743
36	.401520	8.08	.985745	.55	.415775	8.63	.584225
37	.402005	8.07	.985712	.55	.416293	8.62	.583707
38	.402489	8.05	.985679	.55	.416810	8.60	.583190
39	.402972	8.05	.985646	.55	.417326	8.60	.582674
40	.403455	8.05	.985613	.55	.417842	8.60	.582158
41	9.403938	8.03	9.985580	.55	9.418358	8.58	10.581642
42	.404420	8.02	.985547	.55	.418873	8.57	.581127
43	.404901	8.02	.985514	.57	.419387	8.57	.580613
44	.405382	8.00	.985480	.55	.419901	8.57	.580099
45	.405862	7.98	.985447	.55	.420415	8.53	.579585
46	.406341	7.98	.985414	.55	.420927	8.55	.579073
47	.406820	7.98	.985381	.57	.421440	8.53	.578560
48	.407299	7.97	.985347	.55	.421952	8.52	.578048
49	.407777	7.95	.985314	.57	.422463	8.52	.577537
50	.408254	7.95	.985280	.55	.422974	8.50	.577026
51	9.408731	7.93	9.985247	.57	9.423484	8.48	10.576516
52	.409207	7.93	.985213	.55	.423993	8.50	.576007
53	.409682	7.92	.985180	.57	.424503	8.47	.575497
54	.410157	7.92	.985146	.55	.425011	8.47	.574989
55	.410632	7.90	.985113	.57	.425519	8.47	.574481
56	.411106	7.88	.985079	.57	.426027	8.45	.573973
57	.411579	7.88	.985045	.57	.426534	8.45	.573466
58	.412052	7.87	.985011	.55	.427041	8.43	.572959
59	.412524	7.87	.984978	.57	.427547	8.42	.572453
60′	9.412996		9.984944		9.428052		10.57194
	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tan

°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	164°
′	9.412996	7.85	9.984944	.57	9.428052	8.43	10.571948	60′
	.413467	7.85	.984910	.57	.428558	8.40	.571442	59
	.413938	7.83	.984876	.57	.429062	8.40	.570938	58
	.414408	7.83	.984842	.57	.429566	8.40	.570434	57
	.414878	7.82	.984808	.57	.430070	8.38	.569930	56
	.415347	7.80	.984774	.57	.430573	8.37	.569427	55
	.415815	7.80	.984740	.57	.431075	8.37	.568925	54
	.416283	7.80	.984706	.57	.431577	8.37	.568423	53
	.416751	7.77	.984672	.57	.432079	8.35	.567921	52
	.417217	7.78	.984638	.58	.432580	8.33	.567420	51
	.417684	7.77	.984603	.57	.433080	8.33	.566920	50
	9.418150	7.75	9.984569	.57	9.433580	8.33	10.566420	49
	.418615	7.73	.984535	.58	.434080	8.32	.565920	48
	.419079	7.75	.984500	.57	.434579	8.32	.565421	47
	.419544	7.72	.984466	.57	.435078	8.30	.564922	46
	.420007	7.72	.984432	.58	.435576	8.28	.564424	45
	.420470	7.72	.984397	.57	.436073	8.28	.563927	44
	.420933	7.70	.984363	.58	.436570	8.28	.563430	43
	.421395	7.70	.984328	.57	.437067	8.27	.562933	42
	.421857	7.68	.984294	.58	.437563	8.27	.562437	41
	.422318	7.67	.984259	.58	.438059	8.25	.561941	40
	9.422778	7.67	9.984224	.57	9.438554	8.23	10.561446	39
	.423238	7.65	.984190	.58	.439048	8.25	.560952	38
	.423697	7.65	.984155	.58	.439543	8.22	.560457	37
	.424156	7.65	.984120	.58	.440036	8.22	.559964	36
	.424615	7.63	.984085	.58	.440529	8.22	.559471	35
	.425073	7.62	.984050	.58	.441022	8.20	.558978	34
	.425530	7.62	.984015	.57	.441514	8.20	.558486	33
	425987	7.60	.983981	.58	.442006	8.18	.557994	32
	.426443	7.60	.983946	.58	.442497	8.18	.557503	31
	.426899	7.58	.983911	.60	.442988	8.18	557012	30
	9.427354	7.58	9.983875	.58	9.443479	8.15	10.556521	29
	.427809	7.57	.983840	.58	.443968	8.17	.556032	28
	.428263	7.57	.983805	.58	.444458	8.15	.555542	27
	.428717	7.55	.983770	.58	.444947	8.13	.555053	26
	.429170	7.55	.983735	.58	.445435	8.13	.554565	25
	.429623	7.53	.983700	.60	.445923	8.13	.554077	24
	.430075	7.53	.983664	.58	.446411	8.12	.553589	23
	.430527	7.52	.983629	.58	.446898	8.10	.553102	22
	.430978	7.52	.983594	.60	.447384	8.10	.552616	21
	.431429	7.50	.983558	.58	.447870	8.10	.552130	20
	9.431879	7.50	9.983523	.60	9.448356	8.08	10.551644	19
	.432329	7.48	.983487	.58	.448841	8.08	.551159	18
	.432778	7.47	.983452	.60	.449326	8.07	.550674	17
	.433226	7.48	.983416	.58	.449810	8.07	.550190	16
	.433675	7.45	.983381	.60	.450294	8.05	.549706	15
	.434122	7.45	.983345	.60	.450777	8.05	.549223	14
	.434569	7.45	.983309	.60	.451260	8.05	.548740	13
	.435016	7.43	.983273	.58	.451743	8.03	.548257	12
	.435462	7.43	.983238	.60	.452225	8.02	.547775	11
	.435908	7.42	.983202	.60	.452706	8.02	.547294	10
	9.436353	7.42	9.983166	.60	9.453187	8.02	10.546813	9
	.436798	7.40	.983130	.60	.453668	8.00	.546332	8
	.437242	7.40	.983094	.60	.454148	8.00	.545852	7
	.437686	7.38	.983058	.60	.454628	7.98	.545372	6
	.438129	7.38	.983022	.60	.455107	7.98	.544893	5
	.438572	7.37	.982986	.60	.455586	7.97	.544414	4
	.439014	7.37	.982950	.60	.456064	7.97	.543936	3
	.439456	7.35	.982914	.60	.456542	7.95	.543458	2
	.439897	7.35	.982878	.60	.457019	7.95	.542981	1
	9.440338		9.982842		9.457496		10.542504	0
′	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

TABLE XXV.—LOGARITHMIC SINES

16°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	163°
0'	9.440338	7.33	9.982842	.62	9.457496	7.95	10.542504	60'
1	.440778	7.33	.982805	.60	.457973	7.93	.542027	59
2	.441218	7.33	.982769	.60	.458449	7.93	.541551	58
3	.441658	7.30	.982733	.62	.458925	7.92	.541075	57
4	.442096	7.32	.982696	.60	.459400	7.92	.540600	56
5	.442535	7.30	.982660	.60	.459875	7.90	.540125	55
6	.442973	7.28	.982624	.62	.460349	7.90	.539651	54
7	.443410	7.28	.982587	.60	.460823	7.90	.539177	53
8	.443847	7.28	.982551	.62	.461297	7.88	.538703	52
9	.444284	7.27	.982514	.62	.461770	7.87	.538230	51
10	.444720	7.25	.982477	.60	.462242	7.88	.537758	50
11	9.445155	7.25	9.982441	.62	9.462715	7.85	10.537285	49
12	.445590	7.25	.982404	.62	.463186	7.87	.536814	48
13	.446025	7.23	.982367	.60	.463658	7.83	.536342	47
14	.446459	7.23	.982331	.62	.464128	7.85	.535872	46
15	.446893	7.22	.982294	.62	.464599	7.83	.535401	45
16	.447326	7.22	.982257	.62	.465069	7.83	.534931	44
17	.447759	7.20	.982220	.62	.465539	7.82	.534461	43
18	.448191	7.20	.982183	.62	.466008	7.82	.533992	42
19	.448623	7.18	.982146	.62	.466477	7.80	.533523	41
20	.449054	7.18	.982109	.62	.466945	7.80	.533055	40
21	9.449485	7.17	9.982072	.62	9.467413	7.78	10.532587	39
22	.449915	7.17	.982035	.62	.467880	7.78	.532120	38
23	.450345	7.17	.981998	.62	.468347	7.78	.531653	37
24	.450775	7.15	.981961	.62	.468814	7.77	.531186	36
25	.451204	7.13	.981924	.63	.469280	7.77	.530720	35
26	.451632	7.13	.981886	.62	.469746	7.75	.530254	34
27	.452060	7.13	.981849	.62	.470211	7.75	.529789	33
28	.452488	7.12	.981812	.63	.470676	7.75	.529324	32
29	.452915	7.12	.981774	.62	.471141	7.73	.528859	31
30	.453342	7.10	.981737	.62	.471605	7.73	.528395	30
31	9.453768	7.10	9.981700	.63	9.472069	7.72	10.527931	29
32	.454194	7.08	.981662	.62	.472532	7.72	.527468	28
33	.454619	7.08	.981625	.63	.472995	7.70	.527005	27
34	.455044	7.08	.981587	.63	.473457	7.70	.526543	26
35	.455469	7.07	.981549	.62	.473919	7.70	.526081	25
36	.455893	7.05	.981512	.63	.474381	7.68	.525619	24
37	.456316	7.05	.981474	.63	.474842	7.68	.525158	23
38	.456739	7.05	.981436	.62	.475303	7.67	.524697	22
39	.457162	7.03	.981399	.63	.475763	7.67	.524237	21
40	.457584	7.03	.981361	.63	.476223	7.67	.523777	20
41	9.458006	7.02	9.981323	.63	9.476683	7.65	10.523317	19
42	.458427	7.02	.981285	.63	.477142	7.65	.522858	18
43	.458848	7.00	.981247	.63	.477601	7.63	.522399	17
44	.459268	7.00	.981209	.63	.478059	7.63	.521941	16
45	.459688	7.00	.981171	.63	.478517	7.63	.521483	15
46	.460108	6.98	.981133	.63	.478975	7.62	.521025	14
47	.460527	6.98	.981095	.63	.479432	7.62	.520568	13
48	.460946	6.97	.981057	.63	.479889	7.60	.520111	12
49	.461364	6.97	.981019	.63	.480345	7.60	.519655	11
50	.461782	6.95	.980981	.65	.480801	7.60	.519199	10
51	9.462199	6.95	9.980942	.63	9.481257	7.58	10.518743	9
52	.462616	6.93	.980904	.63	.481712	7.58	.518288	8
53	.463032	6.93	.980866	.65	.482167	7.57	.517833	7
54	.463448	6.93	.980827	.63	.482621	7.57	.517379	6
55	.463864	6.92	.980789	.65	.483075	7.57	.516925	5
56	.464279	6.92	.980750	.63	.483529	7.55	.516471	4
57	.464694	6.90	.980712	.65	.483982	7.55	.516018	3
58	.465108	6.90	.980673	.63	.484435	7.53	.515565	2
59	.465522	6.88	.980635	.65	.484887	7.53	.515113	1
60'	9.465935		9.980596		9.485339		10.514661	0'
	Cosine.	*D. 1".*	Sine.	D. 1".	Cotang.	D. 1".	Tang.	73°

Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	154°
9.625948	4.52	9.957276	.98	9.668673	5.48	10.331327	60′
.626219	4.52	.957217	.98	.669002	5.50	.330998	59
.626490	4.50	.957158	.98	.669332	5.48	.330668	58
.626760	4.50	.957099	.98	.669661	5.50	.330339	57
.627030	4.50	.957040	.98	.669991	5.48	.330009	56
.627300	4.50	.956981	1.00	.670320	5.48	.329680	55
.627570	4.50	.956921	.98	.670649	5.47	.329351	54
.627840	4.48	.956862	.98	.670977	5.48	.329023	53
.628109	4.48	.956803	.98	.671306	5.48	.328694	52
.628378	4.48	.956744	1.00	.671635	5.47	.328365	51
.628647	4.48	.956684	.98	.671963	5.47	.328037	50
9.628916	4.48	9.956625	.98	9.672291	5.47	10.327709	49
.629185	4.47	.956566	1.00	.672619	5.47	.327381	48
.629453	4.47	.956506	.98	.672947	5.45	.327053	47
.629721	4.47	.956447	1.00	.673274	5.47	.326726	46
.629989	4.47	.956387	1.00	.673602	5.45	.326398	45
.630257	4.45	.956327	.98	.673929	5.47	.326071	44
.630524	4.47	.956268	1.00	.674257	5.45	.325743	43
.630792	4.45	.956208	1.00	.674584	5.45	.325416	42
.631059	4.45	.956148	.98	.674911	5.43	.325089	41
.631326	4.45	.956089	1.00	.675237	5.45	.324763	40
9.631593	4.43	9.956029	1.00	9.675564	5.43	10.324436	39
.631859	4.43	.955969	1.00	.675890	5.45	.324110	38
.632125	4.45	.955909	1.00	.676217	5.43	.323783	37
.632392	4.43	.955849	1.00	.676543	5.43	.323457	36
.632658	4.42	.955789	1.00	.676869	5.42	.323131	35
.632923	4.43	.955729	1.00	.677194	5.43	.322806	34
.633189	4.42	.955669	1.00	.677520	5.43	.322480	33
.633454	4.42	.955609	.98	.677846	5.42	.322154	32
.633719	4.42	.955548	1.00	.678171	5.42	.321829	31
.633984	4.42	.955488	1.00	.678496	5.42	.321504	30
9.634249	4.42	9.955428	1.00	9.678821	5.42	10.321179	29
.634514	4.40	.955368	1.02	.679146	5.42	.320854	28
.634778	4.40	.955307	1.00	.679471	5.40	.320529	27
.635042	4.40	.955247	1.02	.679795	5.42	.320205	26
.635306	4.40	.955186	1.00	.680120	5.40	.319880	25
.635570	4.40	.955126	1.02	.680444	5.40	.319556	24
.635834	4.38	.955065	1.00	.680768	5.40	.319232	23
.636097	4.38	.955005	1.02	.681092	5.40	.318908	22
.636360	4.38	.954944	1.02	.681416	5.40	.318584	21
.636623	4.38	.954883	1.00	.681740	5.38	.318260	20
9.636886	4.37	9.954823	1.02	9.682063	5.40	10.317937	19
.637148	4.38	.954762	1.02	.682387	5.38	.317613	18
.637411	4.37	.954701	1.02	.682710	5.38	.317290	17
.637673	4.37	.954640	1.02	.683033	5.38	.316967	16
.637935	4.37	.954579	1.02	.683356	5.38	.316644	15
.638197	4.35	.954518	1.02	.683679	5.37	.316321	14
.638458	4.37	.954457	1.02	.684001	5.38	.315999	13
.638720	4.35	.954396	1.02	.684324	5.37	.315676	12
.638981	4.35	.954335	1.02	.684646	5.37	.315354	11
.639242	4.35	.954274	1.02	.684968	5.37	.315032	10
9.639503	4.35	9.954213	1.02	9.685290	5.37	10.314710	9
.639764	4.33	.954152	1.03	.685612	5.37	.314388	8
.640024	4.33	.954090	1.02	.685934	5.35	.314066	7
.640284	4.33	.954029	1.02	.686255	5.37	.313745	6
.640544	4.33	.953968	1.03	.686577	5.35	.313423	5
.640804	4.33	.953906	1.02	.686898	5.35	.313102	4
.641064	4.33	.953845	1.03	.687219	5.35	.312781	3
.641324	4.32	.953783	1.02	.687540	5.35	.312460	2
.641583	4.32	.953722	1.03	.687861	5.35	.312139	1
9.641842		9.953660		9.688182		10.311818	0′
Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	64°

18°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	161°
0′	9.489982	6.48	9.978206	.68	9.511776	7.17	10.488224	60
1	.490371	6.47	.978165	.68	.512206	7.15	.487794	59
2	.490759	6.47	.978124	.68	.512635	7.15	.487365	58
3	.491147	6.47	.978083	.68	.513064	7.15	.486936	57
4	.491535	6.45	.978042	.68	.513493	7.13	.486507	56
5	.491922	6.43	.978001	.70	.513921	7.13	.486079	55
6	.492308	6.45	.977959	.68	.514349	7.13	.485651	54
7	.492695	6.43	.977918	.68	.514777	7.12	.485223	53
8	.493081	6.42	.977877	.70	.515204	7.12	.484796	52
9	.493466	6.42	.977835	.68	.515631	7.10	.484369	51
10	.493851	6.42	.977794	.70	.516057	7.12	.483943	50
11	9.494236	6.42	9.977752	.68	9.516484	7.10	10.483516	49
12	.494621	6.40	.977711	.70	.516910	7.08	.483090	48
13	.495005	6.38	.977669	.68	.517335	7.10	.482665	47
14	.495388	6.40	.977628	.70	.517761	7.08	.482239	46
15	.495772	6.37	.977586	.70	.518186	7.07	.481814	45
16	.496154	6.38	.977544	.68	.518610	7.07	.481390	44
17	.496537	6.37	.977503	.70	.519034	7.07	.480966	43
18	.496919	6.37	.977461	.70	.519458	7.07	.480542	42
19	.497301	6.35	.977419	.70	.519882	7.05	.480118	41
20	.497682	6.37	.977377	.70	.520305	7.05	.479695	40
21	9.498064	6.33	9.977335	.70	9.520728	7.05	10.479272	39
22	.498444	6.35	.977293	.70	.521151	7.03	.478849	38
23	.498825	6.32	.977251	.70	.521573	7.03	.478427	37
24	.499204	6.33	.977209	.70	.521995	7.03	.478005	36
25	.499584	6.32	.977167	.70	.522417	7.02	.477583	35
26	.499963	6.32	.977125	.70	.522838	7.02	.477162	34
27	.500342	6.32	.977083	.70	.523259	7.02	.476741	33
28	.500721	6.30	.977041	.70	.523680	7.00	.476320	32
29	.501099	6.28	.976999	.70	.524100	7.00	.475900	31
30	.501476	6.30	.976957	.72	.524520	7.00	.475480	30
31	9.501854	6.28	9.976914	.70	9.524940	6.98	10.475060	29
32	.502231	6.27	.976872	.70	.525359	6.98	.474641	28
33	.502607	6.28	.976830	.72	.525778	6.98	.474222	27
34	.502984	6.27	.976787	.70	.526197	6.97	.473803	26
35	.503360	6.25	.976745	.72	.526615	6.97	.473385	25
36	.503735	6.25	.976702	.70	.527033	6.97	.472967	24
37	.504110	6.25	.976660	.72	.527451	6.95	.472549	23
38	.504485	6.25	.976617	.72	.527868	6.95	.472132	22
39	.504860	6.23	.976574	.70	.528285	6.95	.471715	21
40	.505234	6.23	.976532	.72	.528702	6.95	.471298	20
41	9.505608	6.22	9.976489	.72	9.529119	6.93	10.470881	19
42	.505981	6.22	.976446	.70	.529535	6.93	.470465	18
43	.506354	6.22	.976404	.72	.529951	6.92	.470049	17
44	.506727	6.20	.976361	.72	.530366	6.92	.469634	16
45	.507099	6.20	.976318	.72	.530781	6.92	.469219	15
46	.507471	6.20	.976275	.72	.531196	6.92	.468804	14
47	.507843	6.18	.976232	.72	.531611	6.90	.468389	13
48	.508214	6.18	.976189	.72	.532025	6.90	.467975	12
49	.508585	6.18	.976146	.72	.532439	6.90	.467561	11
50	.508956	6.17	.976103	.72	.532853	6.88	.467147	10
51	9.509326	6.17	9.976060	.72	9.533266	6.88	10.466734	9
52	.509696	6.15	.976017	.72	.533679	6.88	.466321	8
53	.510065	6.15	.975974	.73	.534092	6.87	.465908	7
54	.510434	6.15	.975930	.72	.534504	6.87	.465496	6
55	.510803	6.15	.975887	.72	.534916	6.87	.465084	5
56	.511172	6.13	.975844	.73	.535328	6.85	.464672	4
57	.511540	6.12	.975800	.72	.535739	6.85	.464261	3
58	.511907	6.13	.975757	.72	.536150	6.85	.463850	2
59	.512275	6.12	.975714	.73	.536561	6.85	.463439	1
60′	9.512642		9.975670		9.536972		10.463028	0′
°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

25°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	154°
0'	9.625948	4.52	9.957276	.98	9.668673	5.48	10.331327	60'
1	.626219	4.52	.957217	.98	.669002	5.50	.330998	59
2	.626490	4.50	.957158	.98	.669332	5.48	.330668	58
3	.626760	4.50	.957099	.98	.669661	5.50	.330339	57
4	.627030	4.50	.957040	.98	.669991	5.48	.330009	56
5	.627300	4.50	.956981	1.00	.670320	5.48	.329680	55
6	.627570	4.50	.956921	.98	.670649	5.47	.329351	54
7	.627840	4 48	.956862	.98	.670977	5.48	.329023	53
8	.628109	4.48	.956803	.98	.671306	5.48	.328694	52
9	.628378	4.48	.956744	1.00	.671635	5.47	.328365	51
10	.628647	4.48	.956684	.98	.671963	5.47	.328037	50
11	9.628916	4.48	9.956625	.98	9.672291	5.47	10.327709	49
12	.629185	4.47	.956566	1.00	.672619	5.47	.327381	48
13	.629453	4.47	.956506	.98	.672947	5.45	.327053	47
14	.629721	4.47	.956447	1.00	.673274	5.47	.326726	46
15	.629989	4.47	.956387	1.00	.673602	5.45	.326398	45
16	.630257	4.45	.956327	.98	.673929	5.47	.326071	44
17	.630524	4.47	.956268	1.00	.674257	5.45	.325743	43
18	.630792	4.45	.956208	1.00	.674584	5.45	.325416	42
19	.631059	4.45	.956148	.98	.674911	5.43	.325089	41
20	.631326	4.45	.956089	1.00	.675237	5.45	.324763	40
21	9.631593	4.43	9.956029	1.00	9.675564	5.43	10.324436	39
22	.631859	4.43	.955969	1.00	.675890	5.45	.324110	38
23	.632125	4.45	.955909	1.00	.676217	5.43	.323783	37
24	.632392	4.43	.955849	1.00	.676543	5.43	.323457	36
25	.632658	4.42	.955789	1.00	.676869	5.42	.323131	35
26	.632923	4.43	.955729	1.00	.677194	5.43	.322806	34
27	.633189	4.42	.955669	1.00	.677520	5.43	.322480	33
28	.633454	4.42	.955609	.98	.677846	5.42	.322154	32
29	.633719	4.42	.955548	1.00	.678171	5.42	.321829	31
30	.633984	4.42	.955488	1.00	.678496	5.42	.321504	30
31	9.634249	4.42	9.955428	1.00	9.678821	5.42	10.321179	29
32	.634514	4.40	.955368	1.02	.679146	5.42	.320854	28
33	.634778	4.40	.955307	1.00	.679471	5.40	.320529	27
34	.635042	4.40	.955247	1.02	.679795	5.42	.320205	26
35	.635306	4.40	.955186	1.00	.680120	5.40	.319880	25
36	.635570	4.40	.955126	1.02	.680444	5.40	.319556	24
37	.635834	4.38	.955065	1.00	.680768	5.40	.319232	23
38	.636097	4 38	.955005	1.02	.681092	5.40	.318908	22
39	.636360	4.38	.954944	1.02	.681416	5.40	.318584	21
40	.636623	4.38	.954883	1.00	.681740	5.38	.318260	20
41	9.636886	4.37	9.954823	1.02	9.682063	5.40	10.317937	19
42	.637148	4.38	.954762	1.02	.682387	5.38	.317613	18
43	.637411	4.37	.954701	1.02	.682710	5.38	.317290	17
44	.637673	4.37	.954640	1.02	.683033	5.38	.316967	16
45	.637935	4.37	.954579	1.02	.683356	5.38	.316644	15
46	.638197	4 35	.954518	1.02	.683679	5.37	.316321	14
47	.638458	4.37	.954457	1.02	.684001	5.38	.315999	13
48	.638720	4.35	.954396	1.02	.684324	5.37	.315676	12
49	.638981	4.35	.954335	1.02	.684646	5.37	.315354	11
50	.639242	4.35	.954274	1.02	.684968	5.37	.315032	10
51	9.639503	4.35	9.954213	1.02	9.685290	5.37	10.314710	9
52	.639764	4.33	.954152	1.03	.685612	5.37	.314388	8
53	.640024	4.33	.954090	1.02	.685934	5.35	.314066	7
54	.640284	4.33	.954029	1.02	.686255	5.37	.313745	6
55	.640544	4.33	.953968	1.03	.686577	5.35	.313423	5
56	.640804	4.33	.953906	1.02	.686898	5.35	.313102	4
57	.641064	4.33	.953845	1.03	.687219	5.35	.312781	3
58	.641324	4.32	.953783	1.02	.687540	5.35	.312460	2
59	.641583	4.32	.953722	1.03	.687861	5.35	.312139	1
60'	9.641842		9.953660		9.688182		10.311818	0'
115°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	64°

20°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	69°
0′	9.534052	5.78	9.972986	.77	9.561066	6.55	10.438934	60′
1	.534399	5.77	.972940	.77	.561459	6.53	.438541	59
2	.534745	5.78	.972894	.77	.561851	6.55	.438149	58
3	.535092	5.77	.972848	.77	.562244	6.53	.437756	57
4	.535438	5.75	.972802	.78	.562636	6.53	.437364	56
5	.535783	5.77	.972755	.77	.563028	6.52	.436972	55
6	.536129	5.75	.972709	.77	.563419	6.53	.436581	54
7	.536474	5.73	.972663	.77	.563811	6.52	.436189	53
8	.536818	5.75	.972617	.78	.564202	6.52	.435798	52
9	.537163	5.73	.972570	.77	.564593	6.50	.435407	51
10	.537507	5.73	.972524	.77	.564983	6.50	.435017	50
11	9.537851	5.72	9.972478	.78	9.565373	6.50	10.434627	49
12	.538194	5.73	.972431	.77	.565763	6.50	.434237	48
13	.538538	5.70	.972385	.78	.566153	6.48	.433847	47
14	.538880	5.72	.972338	.78	.566542	6.50	.433458	46
15	.539223	5.70	.972291	.77	.566932	6.47	.433068	45
16	.539565	5.70	.972245	.78	.567320	6.48	.432680	44
17	.539907	5.68	.972198	.78	.567709	6.48	.432291	43
18	.540249	5.68	.972151	.77	.568098	6.47	.431902	42
19	.540590	5.68	.972105	.78	.568486	6.45	.431514	41
20	.540931	5.68	.972058	.78	.568873	6.47	.431127	40
21	9.541272	5.68	9.972011	.78	9.569261	6.45	10.430739	39
22	.541613	5.67	.971964	.78	.569648	6.45	.430352	38
23	.541953	5.67	.971917	.78	.570035	6.45	.429965	37
24	.542293	5.65	.971870	.78	.570422	6.45	.429578	36
25	.542632	5.65	.971823	.78	.570809	6.43	.429191	35
26	.542971	5.65	.971776	.78	.571195	6.43	.428805	34
27	.543310	5.65	.971729	.78	.571581	6.43	.428419	33
28	.543649	5.63	.971682	.78	.571967	6.42	.428033	32
29	.543987	5.63	.971635	.78	.572352	6.43	.427648	31
30	.544325	5.63	.971588	.80	.572738	6.42	.427262	30
31	9.544663	5.62	9.971540	.78	9.573123	6.40	10.426877	29
32	.545000	5.63	.971493	.78	.573507	6.42	.426493	28
33	.545338	5.60	.971446	.80	.573892	6.40	.426108	27
34	.545674	5.62	.971398	.78	.574276	6.40	.425724	26
35	.546011	5.60	.971351	.80	.574660	6.40	.425340	25
36	.546347	5.60	.971303	.78	.575044	6.38	.424956	24
37	.546683	5.60	.971256	.80	.575427	6.38	.424573	23
38	.547019	5.58	.971208	.78	.575810	6.38	.424190	22
39	.547354	5.58	.971161	.80	.576193	6.38	.423807	21
40	.547689	5.58	.971113	.78	.576576	6.38	.423424	20
41	9.548024	5.58	9.971066	.80	9.576959	6.37	10.423041	19
42	.548359	5.57	.971018	.80	.577341	6.37	.422659	18
43	.548693	5.57	.970970	.80	.577723	6.35	.422277	17
44	.549027	5.55	.970922	.80	.578104	6.37	.421896	16
45	.549360	5.55	.970874	.78	.578486	6.35	.421514	15
46	.549693	5.55	.970827	.80	.578867	6.35	.421133	14
47	.550026	5.55	.970779	.80	.579248	6.35	.420752	13
48	.550359	5.55	.970731	.80	.579629	6.33	.420371	12
49	.550692	5.53	.970683	.80	.580009	6.33	.419991	11
50	.551024	5.53	.970635	.82	.580389	6.33	.419611	10
51	9.551356	5.52	9.970586	.80	9.580769	6.33	10.419231	9
52	.551687	5.52	.970538	.80	.581149	6.32	.418851	8
53	.552018	5.52	.970490	.80	.581528	6.32	.418472	7
54	.552349	5.52	.970442	.80	.581907	6.32	.418093	6
55	.552680	5.50	.970394	.82	.582286	6.32	.417714	5
56	.553010	5.52	.970345	.80	.582665	6.32	.417335	4
57	.553341	5.48	.970297	.80	.583044	6.30	.416956	3
58	.553670	5.50	.970249	.82	.583422	6.30	.416578	2
59	.554000	5.48	.970200	.80	.583800	6.28	.416200	1
60	9.554329		9.970152		9.584177		10.415823	0
	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	69°

21°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	158°
0′	9.554329	5.48	9.970152	.82	9.584177	6.30	10.415823	60′
1	.554658	5.48	.970103	.80	.584555	6.28	.415445	59
2	.554987	5.47	.970055	.82	.584932	6.28	.415068	58
3	.555315	5.47	.970006	.82	.585309	6.28	.414691	57
4	.555643	5.47	.969957	.80	.585686	6.27	.414314	56
5	.555971	5.47	.969909	.82	.586062	6.28	.413938	55
6	.556299	5.45	.969860	.82	.586439	6.27	.413561	54
7	.556626	5.45	.969811	.82	.586815	6.25	.413185	53
8	.556953	5.45	.969762	.80	.587190	6.27	.412810	52
9	.557280	5.43	.969714	.82	.587566	6.25	.412434	51
10	.557606	5.43	.969665	.82	.587941	6.25	.412059	50
11	9.557932	5.43	9.969616	.82	9.588316	6.25	10.411684	49
12	.558258	5.42	.969567	.82	.588691	6.25	.411309	48
13	.558583	5.43	.969518	.82	.589066	6.23	.410934	47
14	.558909	5.42	.969469	.82	.589440	6.23	.410560	46
15	.559234	5.40	.969420	.83	.589814	6.23	.410186	45
16	.559558	5.42	.969370	.82	.590188	6.23	.409812	44
17	.559883	5.40	.969321	.82	.590562	6.22	.409438	43
18	.560207	5.40	.969272	.82	.590935	6.22	.409065	42
19	.560531	5.40	.969223	.83	.591308	6.22	.408692	41
20	.560855	5.38	.969173	.82	.591681	6.22	.408319	40
21	9.561178	5.38	9.969124	.82	9.592054	6.20	10.407946	39
22	.561501	5.38	.969075	.83	.592426	6.22	.407574	38
23	.561824	5.37	.969025	.82	.592799	6.20	.407201	37
24	.562146	5.37	.968976	.83	.593171	6.18	.406829	36
25	.562468	5.37	.968926	.82	.593542	6.20	.406458	35
26	.562790	5.37	.968877	.83	.593914	6.18	.406086	34
27	.563112	5.35	.968827	.83	.594285	6.18	.405715	33
28	.563433	5.37	.968777	.82	.594656	6.18	.405344	32
29	.563755	5.33	.968728	.83	.595027	6.18	.404973	31
30	.564075	5.35	.968678	.83	.595398	6.17	.404602	30
31	9.564396	5.33	9.968628	.83	9.595768	6.17	10.404232	29
32	.564716	5.33	.968578	.83	.596138	6.17	.403862	28
33	.565036	5.33	.968528	.82	.596508	6.17	.403492	27
34	.565356	5.33	.968479	.83	.596878	6.15	.403122	26
35	.565676	5.32	.968429	.83	.597247	6.15	.402753	25
36	.565995	5.32	.968379	.83	.597616	6.15	.402384	24
37	.566314	5.30	.968329	.85	.597985	6.15	.402015	23
38	.566632	5.32	.968278	.83	.598354	6.13	.401646	22
39	.566951	5.30	.968228	.83	.598722	6.15	.401278	21
40	.567269	5.30	.968178	.83	.599091	6.13	.400909	20
41	9.567587	5.28	9.968128	.83	9.599459	6.13	10.400541	19
42	.567904	5.30	.968078	.85	.599827	6.12	.400173	18
43	.568222	5.28	.968027	.83	.600194	6.13	.399806	17
44	.568539	5.28	.967977	.83	.600562	6.12	.399438	16
45	.568856	5.27	.967927	.85	.600929	6.12	.399071	15
46	.569172	5.27	.967876	.83	.601296	6.12	.398704	14
47	.569488	5.27	.967826	.85	.601663	6.10	.398337	13
48	.569804	5.27	.967775	.83	.602029	6.10	.397971	12
49	.570120	5.25	.967725	.85	.602395	6.10	.397605	11
50	.570435	5.27	.967674	.83	.602761	6.10	.397239	10
51	9.570751	5.25	9.967624	.85	9.603127	6.10	10.396873	9
52	.571066	5.23	.967573	.85	.603493	6.08	.396507	8
53	.571380	5.25	.967522	.85	.603858	6.08	.396142	7
54	.571695	5.23	.967471	.83	.604223	6.08	.395777	6
55	.572009	5.23	.967421	.85	.604588	6.08	.395412	5
56	.572323	5.22	.967370	.85	.604953	6.07	.395047	4
57	.572636	5.23	.967319	.85	.605317	6.08	.394683	3
58	.572950	5.22	.967268	.85	.605682	6.07	.394318	2
59	.573263	5.20	.967217	.85	.606046	6.07	.393954	1
60′	9.573575		9.967166		9.606410		10.393590	
111°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Ta	

22°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	157°
0'	9.573575	5.22	9.967166	.85	9.606410	6.05	10.393590	60'
1	.573888	5.20	.967115	.85	.606773	6.07	.393227	59
2	.574200	5.20	.967064	.85	.607137	6.05	.392863	58
3	.574512	5.20	.967013	.87	.607500	6.05	.392500	57
4	.574824	5.20	.966961	.85	.607863	6.03	.392137	56
5	.575136	5.18	.966910	.85	.608225	6.05	.391775	55
6	.575447	5.18	.966859	.85	.608588	6.03	.391412	54
7	.575758	5.18	.966808	.87	.608950	6.03	.391050	53
8	.576069	5.17	.966756	.85	.609312	6.03	.390688	52
9	.576379	5.17	.966705	.87	.609674	6.03	.390326	51
10	.576689	5.17	.966653	.85	.610036	6.02	.389964	50
11	9.576999	5.17	9.966602	.87	9.610397	6.03	10.389603	49
12	.577309	5.15	.966550	.85	.610759	6.02	.389241	48
13	.577618	5.15	.966499	.87	.611120	6.00	.388880	47
14	.577927	5.15	.966447	.87	.611480	6.02	.388520	46
15	.578236	5.15	.966395	.85	.611841	6.00	.388159	45
16	.578545	5.13	.966344	.87	.612201	6.00	.387799	44
17	.578853	5.15	.966292	.87	.612561	6.00	.387439	43
18	.579162	5.13	.966240	.87	.612921	6.00	.387079	42
19	.579470	5.12	.966188	.87	.613281	6.00	.386719	41
20	.579777	5.13	.966136	.85	.613641	5.98	.386359	40
21	9.580085	5.12	9.966085	.87	9.614000	5.98	10.386000	39
22	.580392	5.12	.966033	.87	.614359	5.98	.385641	38
23	.580699	5.10	.965981	.87	.614718	5.98	.385282	37
24	.581005	5.12	.965929	.88	.615077	5.97	.384923	36
25	.581312	5.10	.965876	.87	.615435	5.97	.384565	35
26	.581618	5.10	.965824	.87	.615793	5.97	.384207	34
27	.581924	5.08	.965772	.87	.616151	5.97	.383849	33
28	.582229	5.10	.965720	.87	.616509	5.97	.383491	32
29	.582535	5.08	.965668	.88	.616867	5.95	.383133	31
30	.582840	5.08	.965615	.87	.617224	5.97	.382776	30
31	9.583145	5.07	9.965563	.87	9.617582	5.95	10.382418	29
32	.583449	5.08	.965511	.88	.617939	5.93	.382061	28
33	.583754	5.07	.965458	.87	.618295	5.95	.381705	27
34	.584058	5.05	.965406	.88	.618652	5.93	.381348	26
35	.584361	5.07	.965353	.87	.619008	5.93	.380992	25
36	.584665	5.05	.965301	.88	.619364	5.93	.380636	24
37	.584968	5.07	.965248	.88	.619720	5.93	.380280	23
38	.585272	5.03	.965195	.87	.620076	5.93	.379924	22
39	.585574	5.05	.965143	.88	.620432	5.92	.379568	21
40	.585877	5.03	.965090	.88	.620787	5.92	.379213	20
41	9.586179	5.05	9.965037	.88	9.621142	5.92	10.378858	19
42	.586482	5.02	.964984	.88	.621497	5.92	.378503	18
43	.586783	5.03	.964931	.87	.621852	5.92	.378148	17
44	.587085	5.02	.964879	.88	.622207	5.90	.377793	16
45	.587386	5.03	.964826	.88	.622561	5.90	.377439	15
46	.587688	5.02	.964773	.88	.622915	5.90	.377085	14
47	.587989	5.00	.964720	.90	.623269	5.90	.376731	13
48	.588289	5.02	.964666	.88	.623623	5.88	.376377	12
49	.588590	5.00	.964613	.88	.623976	5.90	.376024	11
50	.588890	5.00	.964560	.88	.624330	5.88	.375670	10
51	9.589190	4.98	9.964507	.88	9.624683	5.88	10.375317	9
52	.589489	5.00	.964454	.90	.625036	5.87	.374964	8
53	.589789	4.98	.964400	.88	.625388	5.88	.374612	7
54	.590088	4.98	.964347	.88	.625741	5.87	.374259	6
55	.590387	4.98	.964294	.90	.626093	5.87	.373907	5
56	.590686	4.97	.964240	.88	.626445	5.87	.373555	4
57	.590984	4.97	.964187	.90	.626797	5.87	.373203	3
[illegible]	.591282	4.97	.964133	.88	.627149	5.87	.372851	2
[illegible]	.591580	4.97	.964080	.90	.627501	5.85	.372499	1
[illegible]	[illegible]91878		9.964026		9.627852		10.372148	0'
	ne.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	67°

Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	156°
9.591878	4.97	9.964026	.90	9.627852	5.85	10.372148	60′
.592176	4.95	.963972	.88	.628203	5.85	.371797	59
.592473	4.95	.963919	.90	.628554	5.85	.371446	58
.592770	4.95	.963865	.90	.628905	5.83	.371095	57
.593067	4.93	.963811	.90	.629255	5.85	.370745	56
.593362	4.93	.963757	.88	.629606	5.83	.370394	55
.593659	4.93	.963704	.90	.629956	5.83	.370044	54
.593955	4.93	.963650	.90	.630306	5.83	.369694	53
.594251	4.93	.963596	.90	.630656	5.82	.369344	52
.594547	4.92	.963542	.90	.631005	5.83	.368995	51
.594842	4.92	.963488	.90	.631355	5.82	.368645	50
9.595137	4.92	9.963434	.92	9.631704	5.82	10.368296	49
.595432	4.92	.963379	.90	.632053	5.82	.367947	48
.595727	4.90	.963325	.90	.632402	5.80	.367598	47
.596021	4.90	.963271	.90	.632750	5.82	.367250	46
.596315	4.90	.963217	.90	.633099	5.80	.366901	45
.596609	4.90	.963163	.92	.633447	5.80	.366553	44
.596903	4.88	.963108	.90	.633795	5.80	.366205	43
.597196	4.90	.963054	.92	.634143	5.78	.365857	42
.597490	4.88	.962999	.90	.634490	5.80	.365510	41
.597783	4.87	.962945	.92	.634838	5.78	.365162	40
9.598075	4.88	9.962890	.90	9.635185	5.78	10.364815	39
.598368	4.87	.962836	.92	.635532	5.78	.364468	38
.598660	4.87	.962781	.90	.635879	5.78	.364121	37
.598952	4.87	.962727	.92	.636226	5.77	.363774	36
.599244	4.87	.962672	.92	.636572	5.78	.363428	35
.599536	4.85	.962617	.92	.636919	5.77	.363081	34
.599827	4.85	.962562	.90	.637265	5.77	.362735	33
.600118	4.85	.962508	.92	.637611	5.75	.362389	32
.600409	4.85	.962453	.92	.637956	5.77	.362044	31
.600700	4.83	.962398	.92	.638302	5.75	.361098	30
9.600990	4.83	9.962343	.92	9.638647	5.75	10.361353	29
.601280	4.83	.962288	.92	.638992	5.75	.361008	28
.601570	4.83	.962233	.92	.639337	5.75	.360663	27
.601860	4.83	.962178	.92	.639682	5.75	.360318	26
.602150	4.82	.962123	.93	.640027	5.73	.359973	25
.602439	4.82	.962067	.92	.640371	5.75	.359629	24
.602728	4.82	.962012	.92	.640716	5.73	.359284	23
.603017	4.80	.961957	.92	.641060	5.73	.358940	22
.603305	4.82	.961902	.93	.641404	5.72	.358596	21
.603594	4.80	.961846	.92	.641747	5.73	.358253	20
9.603882	4.80	9.961791	.93	9.642091	5.72	10.357909	19
.604170	4.78	.961735	.92	.642434	5.72	.357566	18
.604457	4.80	.961680	.93	.642777	5.72	.357223	17
.604745	4.78	.961624	.92	.643120	5.72	.356880	16
.605032	4.78	.961569	.93	.643463	5.72	.356537	15
.605319	4.78	.961513	.92	.643806	5.70	.356194	14
.605606	4.77	.961458	.93	.644148	5.70	.355852	13
.605892	4.78	.961402	.93	.644490	5.70	.355510	12
.606179	4.77	.961346	.93	.644832	5.70	.355168	11
.606465	4.77	.961290	.92	.645174	5.70	.354826	10
9.606751	4.75	9.961235	.93	9.645516	5.68	10.354484	9
.607036	4.77	.961179	.93	.645857	5.70	.354143	8
.607322	4.75	.961123	.93	.646199	5.68	.353801	7
.607607	4.75	.961067	.93	.646540	5.68	.353460	6
.607892	4.75	.961011	.93	.646881	5.68	.353119	5
.608177	4.73	.960955	.93	.647222	5.67	.352778	4
.608461	4.73	.960899	.93	.647562	5.68	.352438	3
.608745	4.73	.960843	.95	.647903	5.67	.352097	2
.609029	4.73	.960786	.93	.648243	5.67	.351757	1
.609313		9.960730		9.648583		10.351417	0
osine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

24°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	155°
0′	9.609313	4.73	9.960730	.93	9.648583	5.67	10.351417	60′
1	.609597	4.72	.960674	.93	.648923	5.67	.351077	59
2	.609880	4.73	.960618	.95	.649263	5.65	.350737	58
3	.610164	4.72	.960561	.93	.649602	5.67	.350398	57
4	.610447	4.70	.960505	.95	.649942	5.65	.350058	56
5	.610729	4.72	.960448	.93	.650281	5.65	.349719	55
6	.611012	4.70	.960392	.95	.650620	5.65	.349380	54
7	.611294	4.70	.960335	.93	.650959	5.63	.349041	53
8	.611576	4.70	.960279	.95	.651297	5.65	.348703	52
9	.611858	4.70	.960222	.95	.651636	5.63	.348364	51
10	.612140	4.68	.960165	.93	.651974	5.63	.348026	50
11	9.612421	4.68	9.960109	.95	9.652312	5.63	10.347688	49
12	.612702	4.68	.960052	.95	.652650	5.63	.347350	48
13	.612983	4.68	.959995	.95	.652988	5.63	.347012	47
14	.613264	4.68	.959938	.93	.653326	5.62	.346674	46
15	.613545	4.67	.959882	.95	.653663	5.62	.346337	45
16	.613825	4.67	.959825	.95	.654000	5.62	.346000	44
17	.614105	4.67	.959768	.95	.654337	5.62	.345663	43
18	.614385	4.67	.959711	.95	.654674	5.62	.345326	42
19	.614665	4.65	.959654	.97	.655011	5.62	.344989	41
20	.614944	4.65	.959596	.95	.655348	5.60	.344652	40
21	9.615223	4.65	9.959539	.95	9.655684	5.60	10.344316	39
22	.615502	4.65	.959482	.95	.656020	5.60	.343980	38
23	.615781	4.65	.959425	.95	.656356	5.60	.343644	37
24	.616060	4.63	.959368	.97	.656692	5.60	.343308	36
25	.616338	4.63	.959310	.95	.657028	5.60	.342972	35
26	.616616	4.63	.959253	.97	.657364	5.58	.342636	34
27	.616894	4.63	.959195	.95	.657699	5.58	.342301	33
28	.617172	4.63	.959138	.97	.658034	5.58	.341966	32
29	.617450	4.62	.959080	.95	.658369	5.58	.341631	31
30	.617727	4.62	.959023	.97	.658704	5.58	.341296	30
31	9.618004	4.62	9.958965	.95	9.659039	5.57	10.340961	29
32	.618281	4.62	.958908	.97	.659373	5.58	.340627	28
33	.618558	4.60	.958850	.97	.659708	5.57	.340292	27
34	.618834	4.60	.958792	.97	.660042	5.57	.339958	26
35	.619110	4.60	.958734	.95	.660376	5.57	.339624	25
36	.619386	4.60	.958677	.97	.660710	5.55	.339290	24
37	.619662	4.60	.958619	.97	.661043	5.57	.338957	23
38	.619938	4.58	.958561	.97	.661377	5.55	.338623	22
39	.620213	4.58	.958503	.97	.661710	5.55	.338290	21
40	.620488	4.58	.958445	.97	.662043	5.55	.337957	20
41	9.620763	4.58	9.958387	.97	9.662376	5.55	10.337624	19
42	.621038	4.58	.958329	.97	.662709	5.55	.337291	18
43	.621313	4.57	.958271	.97	.663042	5.55	.336958	17
44	.621587	4.57	.958213	.98	.663375	5.53	.336625	16
45	.621861	4.57	.958154	.97	.663707	5.53	.336293	15
46	.622135	4.57	.958096	.97	.664039	5.53	.335961	14
47	.622409	4.55	.958038	.98	.664371	5.53	.335629	13
48	.622682	4.57	.957979	.97	.664703	5.53	.335297	12
49	.622956	4.55	.957921	.97	.665035	5.52	.334965	11
50	.623229	4.55	.957863	.98	.665366	5.53	.334634	10
51	9.623502	4.53	9.957804	.97	9.665698	5.52	10.334302	9
52	.623774	4.55	.957746	.98	.666029	5.52	.333971	8
53	.624047	4.53	.957687	.98	.666360	5.52	.333640	7
54	.624319	4.53	.957628	.97	.666691	5.50	.333309	6
55	.624591	4.53	.957570	.98	.667021	5.52	.332979	5
56	.624863	4.53	.957511	.98	.667352	5.50	.332648	4
57	.625135	4.52	.957452	.98	.667682	5.52	.332318	3
58	.625406	4.52	.957393	.97	.668013	5.50	.331987	2
59	.625677	4.52	.957335	.98	.668343	5.50	.331657	1
60′	9.625948		9.957276		9.668673		10.331327	
4° Cosine.		D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	154°
9.625948	4.52	9.957276	.98	9.668673	5.48	10.331327	60′
.626219	4.52	.957217	.98	.669002	5.50	.330998	59
.626490	4.50	.957158	.98	.669332	5.48	.330668	58
.626760	4.50	.957099	.98	.669661	5.50	.330339	57
.627030	4.50	.957040	.98	.669991	5.48	.330009	56
.627300	4.50	.956981	1.00	.670320	5.48	.329680	55
.627570	4.50	.956921	.98	.670649	5.47	.329351	54
.627840	4.48	.956862	.98	.670977	5.48	.329023	53
.628109	4.48	.956803	.98	.671306	5.48	.328694	52
.628378	4.48	.956744	1.00	.671635	5.47	.328365	51
.628647	4.48	.956684	.98	.671963	5.47	.328037	50
9.628916	4.48	9.956625	.98	9.672291	5.47	10.327709	49
.629185	4.47	.956566	1.00	.672619	5.47	.327381	48
.629453	4.47	.956506	.98	.672947	5.45	.327053	47
.629721	4.47	.956447	1.00	.673274	5.47	.326726	46
.629989	4.47	.956387	1.00	.673602	5.45	.326398	45
.630257	4.45	.956327	.98	.673929	5.47	.326071	44
.630524	4.47	.956268	1.00	.674257	5.45	.325743	43
.630792	4.45	.956208	1.00	.674584	5.45	.325416	42
.631059	4.45	.956148	.98	.674911	5.43	.325089	41
.631326	4.45	.956089	1.00	.675237	5.45	.324763	40
9.631593	4.43	9.956029	1.00	9.675564	5.43	10.324436	39
.631859	4.43	.955969	1.00	.675890	5.45	.324110	38
.632125	4.45	.955909	1.00	.676217	5.43	.323783	37
.632392	4.43	.955849	1.00	.676543	5.43	.323457	36
.632658	4.42	.955789	1.00	.676869	5.42	.323131	35
.632923	4.43	.955729	1.00	.677194	5.43	.322806	34
.633189	4.42	.955669	1.00	.677520	5.43	.322480	33
.633454	4.42	.955609	.98	.677846	5.42	.322154	32
.633719	4.42	.955548	1.00	.678171	5.42	.321829	31
.633984	4.42	.955488	1.00	.678496	5.42	.321504	30
9.634249	4.42	9.955428	1.00	9.678821	5.42	10.321179	29
.634514	4.40	.955368	1.02	.679146	5.42	.320854	28
.634778	4.40	.955307	1.00	.679471	5.40	.320529	27
.635042	4.40	.955247	1.02	.679795	5.42	.320205	26
.635306	4.40	.955186	1.00	.680120	5.40	.319880	25
.635570	4.40	.955126	1.02	.680444	5.40	.319556	24
.635834	4.38	.955065	1.00	.680768	5.40	.319232	23
.636097	4.38	.955005	1.02	.681092	5.40	.318908	22
.636360	4.38	.954944	1.02	.681416	5.40	.318584	21
.636623	4.38	.954883	1.00	.681740	5.38	.318260	20
9.636886	4.37	9.954823	1.02	9.682063	5.40	10.317937	19
.637148	4.38	.954762	1.02	.682387	5.38	.317613	18
.637411	4.37	.954701	1.02	.682710	5.38	.317290	17
.637673	4.37	.954640	1.02	.683033	5.38	.316967	16
.637935	4.37	.954579	1.02	.683356	5.38	.316644	15
.638197	4.35	.954518	1.02	.683679	5.37	.316321	14
.638458	4.37	.954457	1.02	.684001	5.38	.315999	13
.638720	4.35	.954396	1.02	.684324	5.37	.315676	12
.638981	4.35	.954335	1.02	.684646	5.37	.315354	11
.639242	4.35	.954274	1.02	.684968	5.37	.315032	10
9.639503	4.35	9.954213	1.02	9.685290	5.37	10.314710	9
.639764	4.33	.954152	1.03	.685612	5.37	.314388	8
.640024	4.33	.954090	1.02	.685934	5.35	.314066	7
.640284	4.33	.954029	1.02	.686255	5.37	.313745	6
.640544	4.33	.953968	1.03	.686577	5.35	.313423	5
.640804	4.33	.953906	1.02	.686898	5.35	.313102	4
.641064	4.33	.953845	1.03	.687219	5.35	.312781	3
.641324	4.32	.953783	1.02	.687540	5.35	.312460	2
.641583	4.32	.953722	1.03	.687861	5.35	.312139	1
9.641842		9.953660		9.688182		10.311818	0
Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

26°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	153°
0'	9.641842	4.32	9.953660	1.02	9.688182	5.33	10.311818	60'
1	.642101	4.32	.953599	1.03	.688502	5.35	.311498	59
2	.642360	4.30	.953537	1.03	.688823	5.33	.311177	58
3	.642618	4.32	.953475	1.03	.689143	5.33	.310857	57
4	.642877	4.30	.953413	1.02	.689463	5.33	.310537	56
5	.643135	4.30	.953352	1.03	.689783	5.33	.310217	55
6	.643393	4.28	.953290	1.03	.690103	5.33	.309897	54
7	.643650	4.30	.953228	1.03	.690423	5.32	.309577	53
8	.643908	4.28	.953166	1.03	.690742	5.33	.309258	52
9	.644165	4.30	.953104	1.03	.691062	5.32	.308938	51
10	.644423	4.28	.953042	1.03	.691381	5.32	.308619	50
11	9.644680	4.27	9.952980	1.03	9.691700	5.32	10.308300	49
12	.644936	4.28	.952918	1.05	.692019	5.32	.307981	48
13	.645193	4.28	.952855	1.03	.692338	5.30	.307662	47
14	.645450	4.27	.952793	1.03	.692656	5.32	.307344	46
15	.645706	4.27	.952731	1.03	.692975	5.30	.307025	45
16	.645962	4.27	.952669	1.05	.693293	5.32	.306707	44
17	.646218	4.27	.952606	1.03	.693612	5.30	.306388	43
18	.646474	4.25	.952544	1.05	.693930	5.30	.306070	42
19	.646729	4.25	.952481	1.03	.694248	5.30	.305752	41
20	.646984	4.27	.952419	1.05	.694566	5.28	.305434	40
21	9.647240	4.23	9.952356	1.03	9.694883	5.30	10.305117	39
22	.647494	4.25	.952294	1.05	.695201	5.28	.304799	38
23	.647749	4.25	.952231	1.05	.695518	5.30	.304482	37
24	.648004	4.23	.952168	1.03	.695836	5.28	.304164	36
25	.648258	4.23	.952106	1.05	.696153	5.28	.303847	35
26	.648512	4.23	.952043	1.05	.696470	5.28	.303530	34
27	.648766	4.23	.951980	1.05	.696787	5.27	.303213	33
28	.649020	4.23	.951917	1.05	.697103	5.28	.302897	32
29	.649274	4.22	.951854	1.05	.697420	5.27	.302580	31
30	.649527	4.23	.951791	1.05	.697736	5.28	.302264	30
31	9.649781	4.22	9.951728	1.05	9.698053	5.27	10.301947	29
32	.650034	4.22	.951665	1.05	.698369	5.27	.301631	28
33	.650287	4.20	.951602	1.05	.698685	5.27	.301315	27
34	.650539	4.22	.951539	1.05	.699001	5.25	.300999	26
35	.650792	4.20	.951476	1.07	.699316	5.27	.300684	25
36	.651044	4.22	.951412	1.05	.699632	5.25	.300368	24
37	.651297	4.20	.951349	1.05	.699947	5.27	.300053	23
38	.651549	4.18	.951286	1.07	.700263	5.25	.299737	22
39	.651800	4.20	.951222	1.05	.700578	5.25	.299422	21
40	.652052	4.20	.951159	1.05	.700893	5.25	.299107	20
41	9.652304	4.18	9.951096	1.07	9.701208	5.25	10.298792	19
42	.652555	4.18	.951032	1.07	.701523	5.23	.298477	18
43	.652806	4.18	.950968	1.05	.701837	5.25	.298163	17
44	.653057	4.18	.950905	1.07	.702152	5.23	.297848	16
45	.653308	4.17	.950841	1.05	.702466	5.25	.297534	15
46	.653558	4.17	.950778	1.07	.702781	5.23	.297219	14
47	.653808	4.18	.950714	1.07	.703095	5.23	.296905	13
48	.654059	4.17	.950650	1.07	.703409	5.22	.296591	12
49	.654309	4.15	.950586	1.07	.703722	5.23	.296278	11
50	.654558	4.17	.950522	1.07	.704036	5.23	.295964	10
51	9.654808	4.17	9.950458	1.07	9.704350	5.22	10.295650	9
52	.655058	4.15	.950394	1.07	.704663	5.22	.295337	8
53	.655307	4.15	.950330	1.07	.704976	5.23	.295024	7
54	.655556	4.15	.950266	1.07	.705290	5.22	.294710	6
55	.655805	4.15	.950202	1.07	.705603	5.22	.294397	5
56	.656054	4.13	.950138	1.07	.705916	5.20	.294084	4
57	.656302	4.15	.950074	1.07	.706228	5.22	.293772	3
58	.656551	4.13	.950010	1.08	.706541	5.22	.293459	2
59	.656799	4.13	.949945	1.07	.706854	5.20	.293146	1
60'	9.657047		9.949881		9.707166		10.292834	0'
63°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	63°

31°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	148°
0′	9.711839	3.52	9.933066	1.27	9.778774	4.77	10.221226	60′
1	.712050	3.50	.932990	1.27	.779060	4.77	.220940	59
2	.712260	3.48	.932914	1.27	.779346	4.77	.220654	58
3	.712469	3.50	.932838	1.27	.779632	4.77	.220368	57
4	.712679	3.50	.932762	1.28	.779918	4.75	.220082	56
5	.712889	3.48	.932685	1.27	.780203	4.77	.219797	55
6	.713098	3.50	.932609	1.27	.780489	4.77	.219511	54
7	.713308	3.48	.932533	1.27	.780775	4.75	.219225	53
8	.713517	3.48	.932457	1.28	.781060	4.77	.218940	52
9	.713726	3.48	.932380	1.27	.781346	4.75	.218654	51
10	.713935	3.48	.932304	1.27	.781631	4.75	.218369	50
11	9.714144	3.47	9.932228	1.28	9.781916	4.75	10.218084	49
12	.714352	3.48	.932151	1.27	.782201	4.75	.217799	48
13	.714561	3.47	.932075	1.28	.782486	4.75	.217514	47
14	.714769	3.48	.931998	1.28	.782771	4.75	.217229	46
15	.714978	3.47	.931921	1.27	.783056	4.75	.216944	45
16	.715186	3.47	.931845	1.28	.783341	4.75	.216659	44
17	.715394	3.47	.931768	1.28	.783626	4.73	.216374	43
18	.715602	3.45	.931691	1.28	.783910	4.75	.216090	42
19	.715809	3.47	.931614	1.28	.784195	4.73	.215805	41
20	.716017	3.45	.931537	1.28	.784479	4.75	.215521	40
21	9.716224	3.47	9.931460	1.28	9.784764	4.73	10.215236	39
22	.716432	3.45	.931383	1.28	.785048	4.73	.214952	38
23	.716639	3.45	.931306	1.28	.785332	4.73	.214668	37
24	.716846	3.45	.931229	1.28	.785616	4.73	.214384	36
25	.717053	3.43	.931152	1.28	.785900	4.73	.214100	35
26	.717259	3.45	.931075	1.28	.786184	4.73	.213816	34
27	.717466	3.45	.930998	1.28	.786468	4.73	.213532	33
28	.717673	3.43	.930921	1.30	.786752	4.73	.213248	32
29	.717879	3.43	.930843	1.28	.787036	4.72	.212964	31
30	.718085	3.43	.930766	1.30	.787319	4.73	.212681	30
31	9.718291	3.43	9.930688	1.28	9.787603	4.72	10.212397	29
32	.718497	3.43	.930611	1.30	.787886	4.73	.212114	28
33	.718703	3.43	.930533	1.28	.788170	4.72	.211830	27
34	.718909	3.42	.930456	1.30	.788453	4.72	.211547	26
35	.719114	3.43	.930378	1.30	.788736	4.72	.211264	25
36	.719320	3.42	.930300	1.28	.789019	4.72	.210981	24
37	.719525	3.42	.930223	1.30	.789302	4.72	.210698	23
38	.719730	3.42	.930145	1.30	.789585	4.72	.210415	22
39	.719935	3.42	.930067	1.30	.789868	4.72	.210132	21
40	.720140	3.42	.929989	1.30	.790151	4.72	.209849	20
41	9.720345	3.40	9.929911	1.30	9.790434	4.70	10.209566	19
42	.720549	3.42	.929833	1.30	.790716	4.72	.209284	18
43	.720754	3.40	.929755	1.30	.790999	4.70	.209001	17
44	.720958	3.40	.929677	1.30	.791281	4.70	.208719	16
45	.721162	3.40	.929599	1.30	.791563	4.72	.208437	15
46	.721366	3.40	.929521	1.32	.791846	4.70	.208154	14
47	.721570	3.40	.929442	1.30	.792128	4.70	.207872	13
48	.721774	3.40	.929364	1.30	.792410	4.70	.207590	12
49	.721978	3.38	.929286	1.32	.792692	4.70	.207308	11
50	.722181	3.40	.929207	1.30	.792974	4.70	.207026	10
51	9.722385	3.38	9.929129	1.32	9.793256	4.70	10.206744	9
52	.722588	3.38	.929050	1.30	.793538	4.68	.206462	8
53	.722791	3.38	.928972	1.32	.793819	4.70	.206181	7
54	.722994	3.38	.928893	1.30	.794101	4.70	.205899	6
55	.723197	3.38	.928815	1.32	.794383	4.68	.205617	5
56	.723400	3.38	.928736	1.32	.794664	4.70	.205336	4
57	.723603	3.37	.928657	1.32	.794946	4.68	.205054	3
58	.723805	3.37	.928578	1.32	.795227	4.68	.204773	2
59	.724007	3.38	.928499	1.32	.795508	4.68	.204492	1
60′	9.724210		9.928420		9.795789		10.204211	0
121°	*Cosine.*	*D. 1".*	Sine.	D. 1".	Cotang.	D. 1".	Tang.	58°

28°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	151°
0′	9.671609	3.97	9.945935	1.12	9.725674	5.08	10.274326	60′
1	.671847	3.95	.945868	1.13	.725979	5.08	.274021	59
2	.672084	3.95	.945800	1.12	.726284	5.07	.273716	58
3	.672321	3.95	.945733	1.12	.726588	5.07	.273412	57
4	.672558	3.95	.945666	1.13	.726892	5.08	.273108	56
5	.672795	3.95	.945598	1.12	.727197	5.07	.272803	55
6	.673032	3.93	.945531	1.12	.727501	5.07	.272499	54
7	.673268	3.95	.945464	1.13	.727805	5.07	.272195	53
8	.673505	3.93	.945396	1.13	.728109	5.05	.271891	52
9	.673741	3.93	.945328	1.12	.728412	5.07	.271588	51
10	.673977	3.93	.945261	1.13	.728716	5.07	.271284	50
11	9.674213	3.92	9.945193	1.13	9.729020	5.05	10.270980	49
12	.674448	3.93	.945125	1.12	.729323	5.05	.270677	48
13	.674684	3.92	.945058	1.13	.729626	5.05	.270374	47
14	.674919	3.93	.944990	1.13	.729929	5.07	.270071	46
15	.675155	3.92	.944922	1.13	.730233	5.03	.269767	45
16	.675390	3.90	.944854	1.13	.730535	5.05	.269465	44
17	.675624	3.92	.944786	1.13	.730838	5.05	.269162	43
18	.675859	3.92	.944718	1.13	.731141	5.05	.268859	42
19	.676094	3.90	.944650	1.13	.731444	5.03	.268556	41
20	.676328	3.90	.944582	1.13	.731746	5.03	.268254	40
21	9.676562	3.90	9.944514	1.13	9.732048	5.05	10.267952	39
22	.676796	3.90	.944446	1.15	.732351	5.03	.267649	38
23	.677030	3.90	.944377	1.13	.732653	5.03	.267347	37
24	.677264	3.90	.944309	1.13	.732955	5.03	.267045	36
25	.677498	3.88	.944241	1.15	.733257	5.02	.266743	35
26	.677731	3.88	.944172	1.13	.733558	5.03	.266442	34
27	.677964	3.88	.944104	1.13	.733860	5.03	.266140	33
28	.678197	3.88	.944036	1.15	.734162	5.02	.265838	32
29	.678430	3.88	.943967	1.13	.734463	5.02	.265537	31
30	.678663	3.87	.943899	1.15	.734764	5.03	.265236	30
31	9.678895	3.88	9.943830	1.15	9.735066	5.02	10.264934	29
32	.679128	3.87	.943761	1.13	.735367	5.02	.264633	28
33	.679360	3.87	.943693	1.15	.735668	5.02	.264332	27
34	.679592	3.87	.943624	1.15	.735969	5.00	.264031	26
35	.679824	3.87	.943555	1.15	.736269	5.02	.263731	25
36	.680056	3.87	.943486	1.15	.736570	5.00	.263430	24
37	.680288	3.85	.943417	1.15	.736870	5.02	.263130	23
38	.680519	3.85	.943348	1.15	.737171	5.00	.262829	22
39	.680750	3.87	.943279	1.15	.737471	5.00	.262529	21
40	.680982	3.85	.943210	1.15	.737771	5.00	.262229	20
41	9.681213	3.83	9.943141	1.15	9.738071	5.00	10.261929	19
42	.681443	3.85	.943072	1.15	.738371	5.00	.261629	18
43	.681674	3.85	.943003	1.15	.738671	5.00	.261329	17
44	.681905	3.83	.942934	1.17	.738971	5.00	.261029	16
45	.682135	3.83	.942864	1.15	.739271	4.98	.260729	15
46	.682365	3.83	.942795	1.15	.739570	5.00	.260430	14
47	.682595	3.83	.942726	1.17	.739870	4.98	.260130	13
48	.682825	3.83	.942656	1.15	.740169	4.98	.259831	12
49	.683055	3.82	.942587	1.17	.740468	4.98	.259532	11
50	.683284	3.83	.942517	1.15	.740767	4.98	.259233	10
51	9.683514	3.82	9.942448	1.17	9.741066	4.98	10.258934	9
52	.683743	3.82	.942378	1.17	.741365	4.98	.258635	8
53	.683972	3.82	.942308	1.15	.741664	4.97	.258336	7
54	.684201	3.82	.942239	1.17	.741962	4.98	.258038	6
55	.684430	3.80	.942169	1.17	.742261	4.97	.257739	5
56	.684658	3.82	.942099	1.17	.742559	4.98	.257441	4
57	.684887	3.80	.942029	1.17	.742858	4.97	.257142	3
58	.685115	3.80	.941959	1.17	.743156	4.97	.256844	2
59	.685343	3.80	.941889	1.17	.743454	4.97	.256546	1
60	9.685571		9.941819		9.743752		10.256248	0′
	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	61°

Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	146°
9.736109	3.23	9.923591	1.37	9.812517	4.62	10.187483	60′
.736303	3.25	.923509	1.37	.812794	4.60	.187206	59
.736498	3.23	.923427	1.37	.813070	4.62	.186930	58
.736692	3.23	.923345	1.37	.813347	4.60	.186653	57
.736886	3.23	.923263	1.37	.813623	4.60	.186377	56
.737080	3.23	.923181	1.38	.813899	4.62	.186101	55
.737274	3.22	.923098	1.37	.814176	4.60	.185824	54
.737467	3.23	.923016	1.38	.814452	4.60	.185548	53
.737661	3.23	.922933	1.37	.814728	4.60	.185272	52
.737855	3.22	.922851	1.38	.815004	4.60	.184996	51
.738048	3.22	.922768	1.37	.815280	4.58	.184720	50
9.738241	3.22	9.922686	1.38	9.815555	4.60	10.184445	49
.738434	3.22	.922603	1.38	.815831	4.60	.184169	48
.738627	3.22	.922520	1.37	.816107	4.58	.183893	47
.738820	3.22	.922438	1.38	.816382	4.60	.183618	46
.739013	3.22	.922355	1.38	.816658	4.58	.183342	45
.739206	3.20	.922272	1.38	.816933	4.60	.183067	44
.739398	3.20	.922189	1.38	.817209	4.58	.182791	43
.739590	3.22	.922106	1.38	.817484	4.58	.182516	42
.739783	3.20	.922023	1.38	.817759	4.60	.182241	41
.739975	3.20	.921940	1.38	.818035	4.58	.181965	40
9.740167	3.20	9.921857	1.38	9.818310	4.58	10.181690	39
.740359	3.18	.921774	1.38	.818585	4.58	.181415	38
.740550	3.20	.921691	1.40	.818860	4.58	.181140	37
.740742	3.20	.921607	1.38	.819135	4.58	.180865	36
.740934	3.18	.921524	1.38	.819410	4.57	.180590	35
.741125	3.18	.921441	1.40	.819684	4.58	.180316	34
.741316	3.20	.921357	1.38	.819959	4.58	.180041	33
.741508	3.18	.921274	1.40	.820234	4.57	.179766	32
.741699	3.17	.921190	1.38	.820508	4.58	.179492	31
.741889	3.18	.921107	1.40	.820783	4.57	.179217	30
9.742080	3.18	9.921023	1.40	9.821057	4.58	10.178943	29
.742271	3.18	.920939	1.38	.821332	4.57	.178668	28
.742462	3.17	.920856	1.40	.821606	4.57	.178394	27
.742652	3.17	.920772	1.40	.821880	4.57	.178120	26
.742842	3.18	.920688	1.40	.822154	4.58	.177846	25
.743033	3.17	.920604	1.40	.822429	4.57	.177571	24
.743223	3.17	.920520	1.40	.822703	4.57	.177297	23
.743413	3.15	.920436	1.40	.822977	4.57	.177023	22
.743602	3.17	.920352	1.40	.823251	4.55	.176749	21
.743792	3.17	.920268	1.40	.823524	4.57	.176476	20
9.743982	3.15	9.920184	1.42	9.823798	4.57	10.176202	19
.744171	3.17	.920099	1.40	.824072	4.55	.175928	18
.744361	3.15	.920015	1.40	.824345	4.57	.175655	17
.744550	3.15	.919931	1.42	.824619	4.57	.175381	16
.744739	3.15	.919846	1.40	.824893	4.55	.175107	15
.744928	3.15	.919762	1.42	.825166	4.55	.174834	14
.745117	3.15	.919677	1.40	.825439	4.57	.174561	13
.745306	3.13	.919593	1.42	.825713	4.55	.174287	12
.745494	3.15	.919508	1.40	.825986	4.55	.174014	11
.745683	3.13	.919424	1.42	.826259	4.55	.173741	10
9.745871	3.15	9.919339	1.42	9.826532	4.55	10.173468	9
.746060	3.13	.919254	1.42	.826805	4.55	.173195	8
.746248	3.13	.919169	1.40	.827078	4.55	.172922	7
.746436	3.13	.919085	1.42	.827351	4.55	.172649	6
.746624	3.13	.919000	1.42	.827624	4.55	.172376	5
.746812	3.12	.918915	1.42	.827897	4.55	.172103	4
.746999	3.13	.918830	1.42	.828170	4.53	.171830	3
.747187	3.12	.918745	1.43	.828442	4.55	.171558	2
.747374	3.13	.918659	1.42	.828715	4.53	.171285	1
9.747562		9.918574		9.828987		10.171013	0
Cosine.	*D. 1".*	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

30°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	149°
0′	9.698970	3.65	9.937531	1.22	9.761439	4.87	10.238561	60′
1	.699189	3.63	.937458	1.22	.761731	4.87	.238269	59
2	.699407	3.65	.937385	1.22	.762023	4.85	.237977	58
3	.699626	3.63	.937312	1.23	.762314	4.87	.237686	57
4	.699844	3.63	.937238	1.22	.762606	4.85	.237394	56
5	.700062	3.63	.937165	1.22	.762897	4.85	.237103	55
6	.700280	3.63	.937092	1.22	.763188	4.85	.236812	54
7	.700498	3.63	.937019	1.22	.763479	4.85	.236521	53
8	.700716	3.62	.936946	1.23	.763770	4.85	.236230	52
9	.700933	3.63	.936872	1.22	.764061	4.85	.235939	51
10	.701151	3.62	.936799	1.23	.764352	4.85	.235648	50
11	9.701368	3.62	9.936725	1.22	9.764643	4.83	10.235357	49
12	.701585	3.62	.936652	1.23	.764933	4.85	.235067	48
13	.701802	3.62	.936578	1.22	.765224	4.83	.234776	47
14	.702019	3.62	.936505	1.23	.765514	4.85	.234486	46
15	.702236	3.60	.936431	1.23	.765805	4.83	.234195	45
16	.702452	3.62	.936357	1.22	.766095	4.83	.233905	44
17	.702669	3.60	.936284	1.23	.766385	4 83	.233615	43
18	.702885	3.60	.936210	1.23	.766675	4.83	.233325	42
19	.703101	3.60	.936136	1.23	.766965	4.83	.233035	41
20	.703317	3.60	.936062	1.23	.767255	4.83	.232745	40
21	9.703533	3.60	9.935988	1.23	9.767545	4.82	10.232455	39
22	.703749	3.58	.935914	1.23	.767834	4.83	.232166	38
23	.703964	3.58	.935840	1.23	.768124	4.83	.231876	37
24	.704179	3.60	.935766	1.23	.768414	4.82	.231586	36
25	.704395	3.58	.935692	1.23	.768703	4.82	.231297	35
26	.704610	3.58	.935618	1.25	.768992	4.82	.231008	34
27	.704825	3.58	.935543	1.23	.769281	4.83	.230719	33
28	.705040	3.57	.935469	1.23	.769571	4.82	.230429	32
29	.705254	3.58	.935395	1.25	.769860	4.80	.230140	31
30	.705469	3.57	.935320	1.23	.770148	4.82	.229852	30
31	9.705683	3.58	9.935246	1.25	9.770437	4.82	10.229563	29
32	.705898	3.57	.935171	1.23	.770726	4.82	.229274	28
33	.706112	3.57	.935097	1.25	.771015	4.80	.228985	27
34	.706326	3.55	.935022	1.23	.771303	4.82	.228697	26
35	.706539	3.57	.934948	1.25	.771592	4.80	.228408	25
36	.706753	3.57	.934873	1.25	.771880	4.80	.228120	24
37	.706967	3.55	.934798	1.25	.772168	4.82	.227832	23
38	.707180	3.55	.934723	1.23	.772457	4.80	.227543	22
39	.707393	3.55	.934649	1.25	.772745	4.80	.227255	21
40	.707606	3.55	.934574	1.25	.773033	4.80	.226967	20
41	9.707819	3.55	9.934499	1.25	9.773321	4.78	10.226679	19
42	.708032	3.55	.934424	1.25	.773608	4.80	.226392	18
43	.708245	3.55	.934349	1.25	.773896	4.80	.226104	17
44	.708458	3.53	.934274	1.25	.774184	4.78	.225816	16
45	.708670	3.53	.934199	1.27	.774471	4.80	.225529	15
46	.708882	3.53	.934123	1.25	.774759	4.78	.225241	14
47	.709094	3.53	.934048	1.25	.775046	4.78	.224954	13
48	.709306	3.53	.933973	1.25	.775333	4.80	.224667	12
49	.709518	3.53	.933898	1.27	.775621	4.78	.224379	11
50	.709730	3.52	.933822	1.25	.775908	4.78	.224092	10
51	9.709941	3.53	9.933747	1.27	9.776195	4.78	10.223805	9
52	.710153	3.52	.933671	1.25	.776482	4.77	.223518	8
53	.710364	3.52	.933596	1.27	.776768	4.78	.223232	7
54	.710575	3.52	.933520	1.25	.777055	4.78	.222945	6
55	.710786	3.52	.933445	1.27	.777342	4.77	.222658	5
56	.710997	3.52	.933369	1.27	.777628	4.78	.222372	4
7	.711208	3.52	.933293	1.27	.777915	4.77	.222085	3
[illegible]	.711419	3.50	.933217	1.27	.778201	4.78	.221799	2
[illegible]	.711629	3.50	.933141	1.25	.778488	4.77	.221512	1
[illegible]	9.711839		9.933066		9.778774		10.221226	0
	osine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	59°

°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	144°
'	9.758591	3.02	9.913365	1.48	9.845227	4.48	10.154773	60'
	.758772	3.00	.913276	1.48	.845496	4.47	.154504	59
	.758952	3.00	.913187	1.47	.845764	4.48	.154236	58
	.759132	3.00	.913099	1.48	.846033	4.48	.153967	57
	.759312	3.00	.913010	1.47	.846302	4.47	.153698	56
	.759492	3.00	.912922	1.48	.846570	4.48	.153430	55
	.759672	3.00	.912833	1.48	.846839	4.48	.153161	54
	.759852	2.98	.912744	1.48	.847108	4.47	.152892	53
	.760031	3.00	.912655	1.48	.847376	4.47	.152624	52
	.760211	2.98	.912566	1.48	.847644	4.48	.152356	51
	.760390	2.98	.912477	1.48	.847913	4.47	.152087	50
	9.760569	2.98	9.912388	1.48	9.848181	4.47	10.151819	49
	.760748	2.98	.912299	1.48	.848449	4.47	.151551	48
	.760927	2.98	.912210	1.48	.848717	4.48	.151283	47
	.761106	2.98	.912121	1.50	.848986	4.47	.151014	46
	.761285	2.98	.912031	1.48	.849254	4.47	.150746	45
	.761464	2.97	.911942	1.48	.849522	4.47	.150478	44
	.761642	2.98	.911853	1.50	.849790	4.45	.150210	43
	.761821	2.97	.911763	1.48	.850057	4.47	.149943	42
	.761999	2.97	.911674	1.50	.850325	4.47	.149675	41
	.762177	2.98	.911584	1.48	.850593	4.47	.149407	40
	9.762356	2.97	9.911495	1.50	9.850861	4.47	10.149139	39
	.762534	2.97	.911405	1.50	.851129	4.45	.148871	38
	.762712	2.95	.911315	1.48	.851396	4.47	.148604	37
	.762889	2.97	.911226	1.50	.851664	4.45	.148336	36
	.763067	2.97	.911136	1.50	.851931	4.47	.148069	35
	.763245	2.95	.911046	1.50	.852199	4.45	.147801	34
	.763422	2.97	.910956	1.50	.852466	4.45	.147534	33
	.763600	2.95	.910866	1.50	.852733	4.47	.147267	32
	.763777	2.95	.910776	1.50	.853001	4.45	.146999	31
	.763954	2.95	.910686	1.50	.853268	4.45	.146732	30
	9.764131	2.95	9.910596	1.50	9.853535	4.45	10.146465	29
	.764308	2.95	.910506	1.52	.853802	4.45	.146198	28
	.764485	2.95	.910415	1.50	.854069	4.45	.145931	27
	.764662	2.93	.910325	1.50	.854336	4.45	.145664	26
	.764838	2.95	.910235	1.52	.854603	4.45	.145397	25
	.765015	2.93	.910144	1.50	.854870	4.45	.145130	24
	.765191	2.93	.910054	1.52	.855137	4.45	.144863	23
	.765367	2.95	.909963	1.50	.855404	4.45	.144596	22
	.765544	2.93	.909873	1.52	.855671	4.45	.144329	21
	.765720	2.93	.909782	1.52	.855938	4.43	.144062	20
	9.765896	2.93	9.909691	1.50	9.856204	4.45	10.143796	19
	.766072	2.92	.909601	1.52	.856471	4.43	.143529	18
	.766247	2.93	.909510	1.52	.856737	4.45	.143263	17
	.766423	2.92	.909419	1.52	.857004	4.43	.142996	16
	.766598	2.93	.909328	1.52	.857270	4.45	.142730	15
	.766774	2.92	.909237	1.52	.857537	4.43	.142463	14
	.766949	2.92	.909146	1.52	.857803	4.43	.142197	13
	.767124	2.93	.909055	1.52	.858069	4.45	.141931	12
	.767300	2.92	.908964	1.52	.858336	4.43	.141664	11
	.767475	2.90	.908873	1.53	.858602	4.43	.141398	10
	9.767649	2.92	9.908781	1.52	9.858868	4.43	10.141132	9
	.767824	2.92	.908690	1.52	.859134	4.43	.140866	8
	.767999	2.90	.908599	1.53	.859400	4.43	.140600	7
	.768173	2.92	.908507	1.52	.859666	4.43	.140334	6
	.768348	2.90	.908416	1.53	.859932	4.43	.140068	5
	.768522	2.92	.908324	1.52	.860198	4.43	.139802	4
	.768697	2.90	.908233	1.53	.860464	4.43	.139536	3
	.768871	2.90	.908141	1.53	.860730	4.43	.139270	2
	.769045	2.90	.908049	1.52	.860995	4.42	.139005	1
	9.769219		9.907958		9.861261	4.43	10.138739	0
5°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	54

32°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	147°
0'	9.724210	3.37	9.928420	1.30	9.795789	4.68	10.204211	60'
1	.724412	3.37	.928342	1.32	.796070	4.68	.203930	59
2	.724614	3.37	.928263	1.33	.796351	4.68	.203649	58
3	.724816	3.35	.928183	1.32	.796632	4.68	.203368	57
4	.725017	3.37	.928104	1.32	.796913	4.68	.203087	56
5	.725219	3.35	.928025	1.32	.797194	4.67	.202806	55
6	.725420	3.37	.927946	1.32	.797474	4.68	.202526	54
7	.725622	3.35	.927867	1.33	.797755	4.68	.202245	53
8	.725823	3.35	.927787	1.32	.798036	4.67	.201964	52
9	.726024	3.35	.927708	1.32	.798316	4.67	.201684	51
10	.726225	3.35	.927629	1.33	.798596	4.68	.201404	50
11	9.726426	3.33	9.927549	1.32	9.798877	4.67	10.201123	49
12	.726626	3.35	.927470	1.33	.799157	4.67	.200843	48
13	.726827	3.33	.927390	1.33	.799437	4.67	.200563	47
14	.727027	3.35	.927310	1.32	.799717	4.67	.200283	46
15	.727228	3.33	.927231	1.33	.799997	4.67	.200003	45
16	.727428	3.33	.927151	1.33	.800277	4.67	.199723	44
17	.727628	3.33	.927071	1.33	.800557	4.65	.199443	43
18	.727828	3.32	.926991	1.33	.800836	4.67	.199164	42
19	.728027	3.33	.926911	1.33	.801116	4.67	.198884	41
20	.728227	3.33	.926831	1.33	.801396	4.65	.198604	40
21	9.728427	3.32	9.926751	1.33	9.801675	4.67	10.198325	39
22	.728626	3.32	.926671	1.33	.801955	4.65	.198045	38
23	.728825	3.32	.926591	1.33	.802234	4.65	.197766	37
24	.729024	3.32	.926511	1.33	.802513	4.65	.197487	36
25	.729223	3.32	.926431	1.33	.802792	4.67	.197208	35
26	.729422	3.32	.926351	1.35	.803072	4.65	.196928	34
27	.729621	3.32	926270	1.33	.803351	4.65	.196649	33
28	.729820	3.30	.926190	1.33	.803630	4.65	.196370	32
29	.730018	3.32	.926110	1.35	.803909	4.63	.196091	31
30	.730217	3.30	.926029	1.33	.804187	4.65	.195813	30
31	9.730415	3.30	9.925949	1.35	9.804466	4.65	10.195534	29
32	.730613	3.30	.925868	1.33	.804745	4.63	.195255	28
33	.730811	3.30	.925788	1.35	.805023	4.65	.194977	27
34	.731009	3.28	.925707	1.35	.805302	4.63	.194698	26
35	.731206	3.30	.925626	1.35	.805580	4.65	.194420	25
36	.731404	3.30	.925545	1.33	.805859	4.63	.194141	24
37	.731602	3.28	.925465	1.35	.806137	4.63	.193863	23
38	.731799	3.28	.925384	1.35	.806415	4.63	.193585	22
39	.731996	3.28	.925303	1.35	.806693	4.63	.193307	21
40	.732193	3.28	.925222	1.35	.806971	4.63	.193029	20
41	9.732390	3.28	9.925141	1.35	9.807249	4.63	10.192751	19
42	.732587	3.28	.925060	1.35	.807527	4.63	.192473	18
43	.732784	3.27	.924979	1.37	.807805	4.63	.192195	17
44	.732980	3.28	.924897	1.35	.808083	4.63	.191917	16
45	.733177	3.27	.924816	1.35	.808361	4.62	.191639	15
46	.733373	3.27	.924735	1.35	.808638	4.63	.191362	14
47	.733569	3.27	.924654	1.37	.808916	4.62	.191084	13
48	.733765	3.27	.924572	1.35	.809193	4.63	.190807	12
49	.733961	3.27	.924491	1.37	.809471	4.62	.190529	11
50	.734157	3.27	.924409	1.35	.809748	4.62	.190252	10
51	9.734353	3.27	9.924328	1.37	9.810025	4.62	10.189975	9
52	.734549	3.25	.924246	1.37	.810302	4.63	.189698	8
53	.734744	3.25	.924164	1.35	.810580	4.62	.189420	7
54	.734939	3.27	.924083	1.37	.810857	4.62	.189143	6
55	.735135	3.25	.924001	1.37	.811134	4.60	.188866	5
56	.735330	3.25	.923919	1.37	.811410	4.62	.188590	4
57	*.735525*	*3.23*	.923837	1.37	.811687	4.62	.188313	3
58	*.735719*	*3.25*	.923755	1.37	.811964	4.62	.188036	2
	.735914	*3.25*	.923673	1.37	.812241	4.60	.187759	1
	9.736109		9.923591		9.812517		10.187483	0
	Cosine.	*D. 1".*	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	142
9.779463	2.80	9.902349	1.60	9.877114	4.38	10.122886	60
.779631	2.78	.902253	1.58	.877377	4.38	.122623	59
.779798	2.80	.902158	1.58	.877640	4.38	.122360	58
.779966	2.78	.902063	1.60	.877903	4.37	.122097	57
.780133	2.78	.901967	1.58	.878165	4.38	.121835	56
.780300	2.78	.901872	1.60	.878428	4.38	.121572	55
.780467	2.78	.901776	1.58	.878691	4.37	.121309	54
.780634	2.78	.901681	1.60	.878953	4.38	.121047	53
.780801	2.78	.901585	1.58	.879216	4.37	.120784	52
.780968	2.77	.901490	1.60	.879478	4.38	.120522	51
.781134	2.78	.901394	1.60	.879741	4.37	.120259	50
9.781301	2.78	9.901298	1.60	9.880003	4.37	10.119997	49
.781468	2.77	.901202	1.60	.880265	4.38	.119735	48
.781634	2.77	.901106	1.60	.880528	4.37	.119472	47
.781800	2.77	.901010	1.60	.880790	4.37	.119210	46
.781966	2.77	.900914	1.60	.881052	4.37	.118948	45
.782132	2.77	.900818	1.60	.881314	4.38	.118686	44
.782298	2.77	.900722	1.60	.881577	4.37	.118423	43
.782464	2.77	.900626	1.62	.881839	4.37	.118161	42
.782630	2.77	.900529	1.60	.882101	4 37	.117899	41
.782796	2.75	.900433	1.60	.882363	4.37	.117637	40
9.782961	2.77	9.900337	1.62	9.882625	4.37	10.117375	39
.783127	2.75	.900240	1.60	.882887	4.35	.117113	38
.783292	2.77	.900144	1.62	.883148	4.37	.116852	37
.783458	2.75	.900047	1.60	.883410	4.37	.116590	36
.783623	2.75	.899951	1.62	.883672	4.37	.116328	35
.783788	2.75	.899854	1.62	.883934	4.37	.116066	34
.783953	2.75	.899757	1.62	.884196	4.35	.115804	33
.784118	2.73	.899660	1.60	.884457	4.37	.115543	32
.784282	2.75	.899564	1.62	.884719	4.35	.115281	31
.784447	2.75	.899467	1.62	.884980	4.37	.115020	30
9.784612	2.73	9.899370	1.62	9.885242	4.37	10.114758	29
.784776	2.75	.899273	1.62	.885504	4.35	.114496	28
.784941	2.73	.899176	1.63	.885765	4.35	.114235	27
.785105	2.73	.899078	1.62	.886026	4.37	.113974	26
.785269	2.73	.898981	1.62	.886288	4.35	.113712	25
.785433	2.73	.898884	1.62	.886549	4.37	.113451	24
.785597	2.73	.898787	1.63	.886811	4.35	.113189	23
.785761	2.73	.898689	1.62	.887072	4.35	.112928	22
.785925	2.73	.898592	1.63	.887333	4.35	.112667	21
.786089	2.72	.898494	1.62	.887594	4.35	.112406	20
9.786252	2.73	9.898397	1.63	9.887855	4.35	10.112145	19
.786416	2.72	.898299	1.62	.888116	4.37	.111884	18
.786579	2.72	.898202	1.63	.888378	4.35	.111622	17
.786742	2.73	.898104	1.63	.888639	4.35	.111361	16
.786906	2.72	.898006	1.63	888900	4.35	.111100	15
.787069	2.72	.897908	1.63	.889161	4.33	.110839	14
.787232	2.72	.897810	1.63	.889421	4.35	.110579	13
.787395	2.70	.897712	1.63	.889682	4.35	.110318	12
.787557	2.72	.897614	1.63	.889943	4.35	.110057	11
.787720	2.72	.897516	1.63	.890204	4.35	.109796	10
9.787883	2.70	9.897418	1.63	9.890465	4.33	10.109535	9
.788045	2.72	.897320	1.63	.890725	4.35	.109275	8
.788208	2.70	.897222	1.65	.890986	4.35	.109014	7
.788370	2.70	.897123	1.63	.891247	4.33	.108753	6
.788532	2.70	.897025	1.65	.891507	4.35	.108493	5
.788694	2.70	.896926	1.63	.891768	4.33	.108232	4
.788856	2.70	.896828	1.65	.892028	4.35	.107972	3
.789018	2.70	.896729	1.63	.892289	4.33	.107711	2
.789180	2.70	.896631	1.65	.892549	4.35	.107451	1
9.789342		9.896532		9.892810		10.107190	0
Cosine.	*D. 1".*	Sine.	D. 1".	Cotang.	D. 1".	Tang.	52°

36°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	143°
0′	9.769219	2.90	9.907958	1.53	9.861261	4.43	10.138739	60′
1	.769393	2.88	.907866	1.53	.861527	4.42	.138473	59
2	.769566	2.90	.907774	1.53	.861792	4.43	.138208	58
3	.769740	2.88	.907682	1.53	.862058	4.42	.137942	57
4	.769913	2.90	.907590	1.53	.862323	4.43	.137677	56
5	.770087	2.88	.907498	1.53	.862589	4.42	.137411	55
6	.770260	2.88	.907406	1.53	.862854	4.42	.137146	54
7	.770433	2.88	.907314	1.53	.863119	4.43	.136881	53
8	.770606	2.88	.907222	1.55	.863385	4.42	.136615	52
9	.770779	2.88	.907129	1.53	.863650	4.42	.136350	51
10	.770952	2.88	.907037	1.53	.863915	4.42	.136085	50
11	9.771125	2.88	9.906945	1.55	9.864180	4.42	10.135820	49
12	.771298	2.87	.906852	1.53	.864445	4.42	.135555	48
13	.771470	2.88	.906760	1.55	.864710	4.42	.135290	47
14	.771643	2.87	.906667	1.53	.864975	4.42	.135025	46
15	.771815	2.87	.906575	1.55	.865240	4.42	.134760	45
16	.771987	2.87	.906482	1.55	.865505	4.42	.134495	44
17	.772159	2.87	.906389	1.55	.865770	4.42	.134230	43
18	.772331	2.87	.906296	1.53	.866035	4.42	.133965	42
19	.772503	2.87	.906204	1.55	.866300	4.40	.133700	41
20	.772675	2.87	.906111	1.55	.866564	4.42	.133436	40
21	9.772847	2.85	9.906018	1.55	9.866829	4.42	10.133171	39
22	.773018	2.87	.905925	1.55	.867094	4.40	.132906	38
23	.773190	2.85	.905832	1.55	.867358	4.42	.132642	37
24	.773361	2.87	.905739	1.57	.867623	4.40	.132377	36
25	.773533	2.85	.905645	1.55	.867887	4.42	.132113	35
26	.773704	2.85	.905552	1.55	.868152	4.40	.131848	34
27	.773875	2.85	.905459	1.55	.868416	4.40	.131584	33
28	.774046	2.85	.905366	1.57	.868680	4.42	.131320	32
29	.774217	2.85	.905272	1.55	.868945	4.40	.131055	31
30	.774388	2.83	.905179	1.57	.869209	4.40	.130791	30
31	9.774558	2.85	9.905085	1.55	9.869473	4.40	10.130527	29
32	.774729	2.83	.904992	1.57	.869737	4.40	.130263	28
33	.774899	2.85	.904898	1.57	.870001	4.40	.129999	27
34	.775070	2.83	.904804	1.55	.870265	4.40	.129735	26
35	.775240	2.83	.904711	1.57	.870529	4.40	.129471	25
36	.775410	2.83	.904617	1.57	.870793	4.40	.129207	24
37	.775580	2.83	.904523	1.57	.871057	4.40	.128943	23
38	.775750	2.83	.904429	1.57	.871321	4.40	.128679	22
39	.775920	2.83	.904335	1.57	.871585	4.40	.128415	21
40	.776090	2.82	.904241	1.57	.871849	4.38	.128151	20
41	9.776259	2.83	9.904147	1.57	9.872112	4.40	10.127888	19
42	.776429	2.82	.904053	1.57	.872376	4.40	.127624	18
43	.776598	2.83	.903959	1.58	.872640	4.38	.127360	17
44	.776768	2.82	.903864	1.57	.872903	4.40	.127097	16
45	.776937	2.82	.903770	1.57	.873167	4.38	.126833	15
46	.777106	2.82	.903676	1.58	.873430	4.40	.126570	14
47	.777275	2.82	.903581	1.57	.873694	4.38	.126306	13
48	.777444	2.82	.903487	1.58	.873957	4.38	.126043	12
49	.777613	2.80	.903392	1.57	.874220	4.40	.125780	11
50	.777781	2.82	.903298	1.58	.874484	4.38	.125516	10
51	9.777950	2.82	9.903203	1.58	9.874747	4.38	10.125253	9
52	.778119	2.80	.903108	1.57	.875010	4.38	.124990	8
53	.778287	2.80	.903014	1.58	.875273	4.40	.124727	7
54	.778455	2.82	.902919	1.58	.875537	4.38	.124463	6
55	.778624	2.80	.902824	1.58	.875800	4.38	.124200	5
56	.778792	2.80	.902729	1.58	.876063	4.38	.123937	4
57	.778960	2.80	.902634	1.58	.876326	4.38	.123674	3
58	.779128	2.78	.902539	1.58	.876589	4.38	.123411	2
59	.779295	2.80	.902444	1.58	.876852	4.37	.123148	1
60	9.779463		9.902349		9.877114		10.122886	0
	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

37°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	142
0′	9.779463	2.80	9.902349	1.60	9.877114	4.38	10.122886	60
1	.779631	2.78	.902253	1.58	.877377	4.38	.122623	59
2	.779798	2.80	.902158	1.58	.877640	4.38	.122360	58
3	.779966	2.78	.902063	1.60	.877903	4.37	.122097	57
4	.780133	2.78	.901967	1.58	.878165	4.38	.121835	56
5	.780300	2.78	.901872	1.60	.878428	4.38	.121572	55
6	.780467	2.78	.901776	1.58	.878691	4.37	.121309	54
7	.780634	2.78	.901681	1.60	.878953	4.38	.121047	53
8	.780801	2.78	.901585	1.58	.879216	4.37	.120784	52
9	.780968	2.77	.901490	1.60	.879478	4.38	.120522	51
10	.781134	2.78	.901394	1.60	.879741	4.37	.120259	50
11	9.781301	2.78	9.901298	1.60	9.880003	4.37	10.119997	49
12	.781468	2.77	.901202	1.60	.880265	4.38	.119735	48
13	.781634	2.77	.901106	1.60	.880528	4.37	.119472	47
14	.781800	2.77	.901010	1.60	.880790	4.37	.119210	46
15	.781966	2.77	.900914	1.60	.881052	4.37	.118948	45
16	.782132	2.77	.900818	1.60	.881314	4.38	.118686	44
17	.782298	2.77	.900722	1.60	.881577	4.37	.118423	43
18	.782464	2.77	.900626	1.62	.881839	4.37	.118161	42
19	.782630	2.77	.900529	1.60	.882101	4 37	.117899	41
20	.782796	2.75	.900433	1.60	.882363	4.37	.117637	40
21	9.782961	2.77	9.900337	1.62	9.882625	4.37	10.117375	39
22	.783127	2.75	.900240	1.60	.882887	4.35	.117113	38
23	.783292	2.77	.900144	1.62	.883148	4.37	.116852	37
24	.783458	2.75	.900047	1.60	.883410	4.37	.116590	36
25	.783623	2.75	.899951	1.62	.883672	4.37	.116328	35
26	.783788	2.75	.899854	1.62	.883934	4.37	.116066	34
27	.783953	2.75	.899757	1.62	.884196	4.35	.115804	33
28	.784118	2.73	.899660	1.60	.884457	4.37	.115543	32
29	.784282	2.75	.899564	1.62	.884719	4.35	.115281	31
30	.784447	2.75	.899467	1.62	.884980	4.37	.115020	30
31	9.784612	2.73	9.899370	1.62	9.885242	4.37	10.114758	29
32	.784776	2.75	.899273	1.62	.885504	4.35	.114496	28
33	.784941	2.73	.899176	1.63	.885765	4.35	.114235	27
34	.785105	2.73	.899078	1.62	.886026	4.37	.113974	26
35	.785269	2.73	.898981	1.62	.886288	4.35	.113712	25
36	.785433	2.73	.898884	1.62	.886549	4.37	.113451	24
37	.785597	2.73	.898787	1.63	.886811	4.35	.113189	23
38	.785761	2.73	.898689	1.62	.887072	4.35	.112928	22
39	.785925	2.73	.898592	1.63	.887333	4.35	.112667	21
40	.786089	2.72	.898494	1.62	.887594	4.35	.112406	20
41	9.786252	2.73	9.898397	1.63	9.887855	4.35	10.112145	19
42	.786416	2.72	.898299	1.62	.888116	4.37	.111884	18
43	.786579	2.72	.898202	1.63	.888378	4.35	.111622	17
44	.786742	2.73	.898104	1.63	.888639	4.35	.111361	16
45	.786906	2.72	.898006	1.63	888900	4.35	.111100	15
46	.787069	2.72	.897908	1.63	.889161	4.33	.110839	14
47	.787232	2.72	.897810	1.63	.889421	4.35	.110579	13
48	.787395	2.70	.897712	1.63	.889682	4.35	.110318	12
49	.787557	2.72	.897614	1.63	.889943	4.35	.110057	11
50	.787720	2.72	.897516	1.63	.890204	4.35	.109796	10
51	9.787883	2.70	9.897418	1.63	9.890465	4.33	10.109535	9
52	.788045	2.72	.897320	1.63	.890725	4.35	.109275	8
53	.788208	2.70	.897222	1.65	.890986	4.35	.109014	7
54	.788370	2.70	.897123	1.63	.891247	4.33	.108753	6
55	.788532	2.70	.897025	1.65	.891507	4.35	.108493	5
56	.788694	2.70	.896926	1.63	.891768	4.33	.108232	4
57	.788856	2.70	.896828	1.65	.892028	4.35	.107972	3
58	.789018	2.70	.896729	1.63	.892289	4.33	.107711	2
59	.789180	2.70	.896631	1.65	.892549	4.35	.107451	1
60′	9.789342		9.896532		9.892810		10.107190	0
52°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

38°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	141°
0′	9.789342	2.70	9.896532	1.65	9.892810	4.33	10.107190	60′
1	.789504	2.68	.896433	1.63	.893070	4.35	.106930	59
2	.789665	2.70	.896335	1.65	.893331	4.33	.106669	58
3	.789827	2.68	.896236	1.65	.893591	4.33	.106409	57
4	.789988	2.68	.896137	1.65	.893851	4.33	.106149	56
5	.790149	2.68	.896038	1.65	.894111	4.35	.105889	55
6	.790310	2.68	.895939	1.65	.894372	4.33	.105628	54
7	.790471	2.68	.895840	1.65	.894632	4.33	.105368	53
8	.790632	2.68	.895741	1.67	.894892	4.33	.105108	52
9	.790793	2.68	.895641	1.65	.895152	4.33	.104848	51
10	.790954	2.68	.895542	1.65	.895412	4.33	.104588	50
11	9.791115	2.67	9.895443	1.67	9.895672	4.33	10.104328	49
12	.791275	2.68	.895343	1.65	.895932	4.33	.104068	48
13	.791436	2.67	.895244	1.65	.896192	4.33	.103808	47
14	.791596	2.68	.895145	1.67	.896452	4.33	.103548	46
15	.791757	2.67	.895045	1.67	.896712	4.32	.103288	45
16	.791917	2.67	.894945	1.65	.896971	4.33	.103029	44
17	.792077	2.67	.894846	1.67	.897231	4.33	.102769	43
18	.792237	2.67	.894746	1.67	.897491	4.33	.102509	42
19	.792397	2.67	.894646	1.67	.897751	4.32	.102249	41
20	.792557	2.65	.894546	1.67	.898010	4.33	.101990	40
21	9.792716	2.67	9.894446	1.67	9.898270	4.33	10.101730	39
22	.792876	2.65	.894346	1.67	.898530	4.32	.101470	38
23	.793035	2.67	.894246	1.67	.898789	4.33	.101211	37
24	.793195	2.65	.894146	1.67	.899049	4.32	.100951	36
25	.793354	2.67	.894046	1.67	.899308	4.33	.100692	35
26	.793514	2.65	.893946	1.67	.899568	4.32	.100432	34
27	.793673	2.65	.893846	1.68	.899827	4.33	.100173	33
28	.793832	2.65	.893745	1.67	.900087	4.32	.099913	32
29	.793991	2.65	.893645	1.68	.900346	4.32	.099654	31
30	.794150	2.63	.893544	1.67	.900605	4.32	.099395	30
31	9.794308	2.65	9.893444	1.68	9.900864	4.33	10.099136	29
32	.794467	2.65	.893343	1.67	.901124	4.32	.098876	28
33	.794626	2.63	.893243	1.68	.901383	4.32	.098617	27
34	.794784	2.63	.893142	1.68	.901642	4.32	.098358	26
35	.794942	2.65	.893041	1.68	.901901	4.32	.098099	25
36	.795101	2.63	.892940	1.68	.902160	4.33	.097840	24
37	.795259	2.63	.892839	1.67	.902420	4.32	.097580	23
38	.795417	2.63	.892739	1.68	.902679	4.32	.097321	22
39	.795575	2.63	.892638	1.70	.902938	4.32	.097062	21
40	.795733	2.63	.892536	1.68	.903197	4.32	.096803	20
41	9.795891	2.63	9.892435	1.68	9.903456	4.30	10.096544	19
42	.796049	2.62	.892334	1.68	.903714	4.32	.096286	18
43	.796206	2.63	.892233	1.68	.903973	4.32	.096027	17
44	.796364	2.62	.892132	1.70	.904232	4.32	.095768	16
45	.796521	2.63	.892030	1.68	.904491	4.32	.095509	15
46	.796679	2.62	.891929	1.70	.904750	4.30	.095250	14
47	.796836	2.62	.891827	1.68	.905008	4.32	.094992	13
48	.796993	2.62	.891726	1.70	.905267	4.32	.094733	12
49	.797150	2.62	.891624	1.68	.905526	4.32	.094474	11
50	.797307	2.62	.891523	1.70	.905785	4.30	.094215	10
51	9.797464	2.62	9.891421	1.70	9.906043	4.32	10.093957	9
52	.797621	2.60	.891319	1.70	.906302	4.30	.093698	8
53	.797777	2.62	.891217	1.70	.906560	4.32	.093440	7
54	.797934	2.62	.891115	1.70	.906819	4.30	.093181	6
55	.798091	2.60	.891013	1.70	.907077	4.32	.092923	5
56	.798247	2.60	.890911	1.70	.907336	4.30	.092664	4
57	.798403	2.62	.890809	1.70	.907594	4.32	.092406	3
58	.798560	2.60	.890707	1.70	.907853	4.30	.092147	2
[illegible]	.798716	2.60	.890605	1.70	.908111	4.30	.091889	1
[illegible]	9.798872		9.890503		9.908369		10.091631	[illegible]
	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	138°
	9.816943	2.42	9.877780	1.83	9.939163	4.25	10.060837	60′
	.817088	2.42	.877670	1.83	.939418	4.25	.060582	59
	.817233	2.43	.877560	1.83	.939673	4.25	.060327	58
	.817379	2.42	.877450	1.83	.939928	4.25	.060072	57
	.817524	2.40	.877340	1.83	.940183	4.27	.059817	56
	.817668	2.42	.877230	1.83	.940439	4.25	.059561	55
	.817813	2.42	.877120	1.83	.940694	4.25	.059306	54
	.817958	2.42	.877010	1.85	.940949	4.25	.059051	53
	.818103	2.40	.876899	1.83	.941204	4.25	.058796	52
	.818247	2.42	.876789	1.85	.941459	4.23	.058541	51
	.818392	2.40	.876678	1.83	.941713	4.25	.058287	50
	9.818536	2.42	9.876568	1.85	9.941968	4.25	10.058032	49
	.818681	2.40	.876457	1.83	.942223	4.25	.057777	48
	.818825	2.40	.876347	1.85	.942478	4.25	.057522	47
	.818969	2.40	.876236	1.85	.942733	4.25	.057267	46
	.819113	2.40	.876125	1.85	.942988	4.25	.057012	45
	.819257	2.40	.876014	1.83	.943243	4.25	.056757	44
	.819401	2.40	.875904	1.85	.943498	4.23	.056502	43
	.819545	2.40	.875793	1.85	.943752	4.25	.056248	42
	.819689	2.38	.875682	1.85	.944007	4.25	.055993	41
	.819832	2.40	.875571	1.87	.944262	4.25	.055738	40
	9.819976	2.40	9.875459	1.85	9.944517	4.23	10.055483	39
	.820120	2.38	.875348	1.85	.944771	4.25	.055229	38
	.820263	2.38	.875237	1.85	.945026	4.25	.054974	37
	.820406	2.40	.875126	1.87	.945281	4.23	.054719	36
	.820550	2.38	.875014	1.85	.945535	4.25	.054465	35
	.820693	2.38	.874903	1.87	.945790	4.25	.054210	34
	.820836	2.38	.874791	1.85	.946045	4.23	.053955	33
	.820979	2.38	.874680	1.87	.946299	4.25	.053701	32
	.821122	2.38	.874568	1.87	.946554	4.23	.053446	31
	.821265	2.37	.874456	1.87	.946808	4.25	.053192	30
	9.821407	2.38	9.874344	1.87	9.947063	4.25	10.052937	29
	.821550	2.38	.874232	1.85	.947318	4.23	.052682	28
	.821693	2.37	.874121	1.87	.947572	4.25	.052428	27
	.821835	2.37	.874009	1.88	.947827	4.23	.052173	26
	.821977	2.38	.873896	1.87	.948081	4.23	.051919	25
	.822120	2.37	.873784	1.87	.948335	4.25	.051665	24
	.822262	2.37	.873672	1.87	.948590	4.23	.051410	23
	.822404	2.37	.873560	1.87	.948844	4.25	.051156	22
	.822546	2.37	.873448	1.88	.949099	4.23	.050901	21
	.822688	2.37	.873335	1.87	.949353	4.25	.050647	20
	9.822830	2.37	9.873223	1.88	9.949608	4.23	10.050392	19
	.822972	2.37	.873110	1.87	.949862	4.23	.050138	18
	.823114	2.35	.872998	1.88	.950116	4.25	.049884	17
	.823255	2.37	.872885	1.88	.950371	4.23	.049629	16
	.823397	2.37	.872772	1.88	.950625	4.23	.049375	15
	.823539	2.35	.872659	1.87	.950879	4.23	.049121	14
	.823680	2.35	.872547	1.88	.951133	4.25	.048867	13
	.823821	2.37	.872434	1.88	.951388	4.23	.048612	12
	.823963	2.35	.872321	1.88	.951642	4.23	.048358	11
	.824104	2.35	.872208	1.88	.951896	4.23	.048104	10
	9.824245	2.35	9.872095	1.90	9.952150	4.25	10.047850	9
	.824386	2.35	.871981	1.88	.952405	4.23	.047595	8
	.824527	2.35	.871868	1.88	.952659	4.23	.047341	7
	.824668	2.33	.871755	1.90	.952913	4.23	.047087	6
	.824808	2.35	.871641	1.88	.953167	4.23	.046833	5
	.824949	2.35	.871528	1.90	.953421	4.23	.046579	4
	.825090	2.33	.871414	1.88	.953675	4.23	.046325	3
	.825230	2.35	.871301	1.90	.953929	4.23	.046071	2
	.825371	2.33	.871187	1.90	.954183	4.23	.045817	1
′	9.825511		9.871073		9.954437		10.045563	
1°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	

40°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	139°
0'	9.808067	2.52	9.884254	1.77	9.923814	4.27	10.076186	60'
1	.808218	2.50	.884148	1.77	.924070	4.28	.075930	59
2	.808368	2.52	.884042	1.77	.924327	4.27	075673	58
3	.808519	2.50	.883936	1.78	.924583	4.28	.075417	57
4	.808669	2.50	.883829	1.77	.924840	4.27	.075160	56
5	.808819	2.50	.883723	1.77	.925096	4.27	.074904	55
6	.808969	2.50	.883617	1.78	.925352	4.28	.074648	54
7	.809119	2.50	.883510	1.77	.925609	4.27	.074391	53
8	.809269	2.50	.883404	1.78	.925865	4.28	.074135	52
9	.809419	2.50	.883297	1.77	.926122	4.27	.073878	51
10	.809569	2.48	.883191	1.78	.926378	4.27	.073622	50
11	9.809718	2.50	9.883084	1.78	9.926634	4.27	10.073366	49
12	.809868	2.48	.882977	1.77	.926890	4.28	.073110	48
13	.810017	2.50	.882871	1.78	.927147	4.27	.072853	47
14	.810167	2.48	.882764	1.78	.927403	4.27	.072597	46
15	.810316	2.48	.882657	1.78	.927659	4.27	.072341	45
16	.810465	2.48	.882550	1.78	.927915	4.27	.072085	44
17	.810614	2.48	.882443	1.78	.928171	4.27	.071829	43
18	.810763	2.48	.882336	1.78	.928427	4.28	.071573	42
19	.810912	2.48	.882229	1.80	.928684	4.27	.071316	41
20	.811061	2.48	.882121	1.78	.928940	4.27	.071060	40
21	9.811210	2.47	9.882014	1.78	9.929196	4.27	10.070804	39
22	.811358	2.48	.881907	1.80	.929452	4.27	.070548	38
23	.811507	2.47	.881799	1.78	.929708	4.27	.070292	37
24	.811655	2.48	.881692	1.80	.929964	4.27	.070036	36
25	.811804	2.47	.881584	1.78	.930220	4.25	.069780	35
26	.811952	2.47	.881477	1.80	.930475	4.27	.069525	34
27	.812100	2.47	.881369	1.80	.930731	4.27	.069269	33
28	.812248	2.47	.881261	1.80	.930987	4.27	.069013	32
29	.812396	2.47	.881153	1.78	.931243	4.27	.068757	31
30	.812544	2.47	.881046	1.80	.931499	4.27	.068501	30
31	9.812692	2.47	9.880938	1.80	9.931755	4.25	10.068245	29
32	.812840	2.47	.880830	1.80	.932010	4 27	.067990	28
33	.812988	2.45	.880722	1.82	.932266	4.27	.067734	27
34	.813135	2.47	.880613	1.80	.932522	4.27	.067478	26
35	.813283	2.45	.880505	1.80	.932778	4.25	.067222	25
36	.813430	2.47	.880397	1.80	.933033	4.27	.066967	24
37	.813578	2.45	.880289	1.82	.933289	4.27	.066711	23
38	.813725	2.45	.880180	1.80	.933545	4.25	.066455	22
39	.813872	2.45	.880072	1.82	.933800	4.27	.066200	21
40	.814019	2.45	.879963	1.80	.934056	4.25	.065944	20
41	9.814166	2.45	9.879855	1.82	9.934311	4.27	10.065689	19
42	.814313	2.45	.879746	1.82	.934567	4.25	.065433	18
43	.814460	2.45	.879637	1.80	.934822	4.27	.065178	17
44	.814607	2.43	.879529	1.82	.935078	4.25	.064922	16
45	.814753	2.45	.879420	1.82	.935333	4.27	.064667	15
46	.814900	2.43	.879311	1.82	.935589	4.25	.064411	14
47	.815046	2.45	.879202	1.82	.935844	4.27	.064156	13
48	.815193	2.43	.879093	1.82	.936100	4.25	.063900	12
49	.815339	2.43	.878984	1.82	.936355	4.27	.063645	11
50	.815485	2.45	.878875	1.82	.936611	4.25	.063389	10
51	9.815632	2.43	9.878766	1.83	9.936866	4.25	10.063134	9
52	.815778	2.43	.878656	1.82	.937121	4.27	.062879	8
53	.815924	2.42	.878547	1.82	.937377	4.25	.062623	7
54	.816069	2.43	.878438	1.83	.937632	4.25	.062368	6
55	.816215	2.43	.878328	1.82	.937887	4.25	.062113	5
56	.816361	2.43	.878219	1.83	.938142	4.27	.061858	4
57	.816507	2.42	.878109	1.83	.938398	4.25	.061602	3
[illegible]	.816652	2.43	.877999	1.82	.938653	4.25	.061347	2
[illegible]	.816798	2.42	.877890	1.83	.938908	4.25	.061092	1
[illegible]	.816943		9.877780		9.939163		10.060837	0
	ine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	[illegible]

°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	136°
'	9.833783	2.27	9.864127	1.95	9.969656	4.22	10.030344	60'
	.833919	2.25	.864010	1.97	.969909	4.22	.030091	59
	.834054	2.25	.863892	1.97	.970162	4.23	.029838	58
	.834189	2.27	.863774	1.97	.970416	4.2[illegible]	.029584	57
	.834325	2.25	.863656	1.97	.970669	4.22	.029331	56
	.834460	2.25	.863538	1.98	.970922	4.22	.029078	55
	.834595	2.25	.863419	1.97	.971175	4.23	.028825	54
	.834730	2.25	.863301	1.97	.971429	4.22	.028571	53
	.834865	2.23	.863183	1.98	.971682	4.22	.028318	52
	.834999	2.25	.863064	1.97	.971935	4.22	.028065	51
	.835134	2.25	.862946	1.98	.972188	4.22	.027812	50
	9.835269	2.23	9.862827	1.97	9.972441	4.23	10.027559	49
	.835403	2.25	.862709	1.98	.972695	4.22	.027305	48
	.835538	2.23	.862590	1.98	.972948	4.22	.027052	47
	.835672	2.25	.862471	1.97	.973201	4.22	.026799	46
	.835807	2.23	.862353	1.98	.973454	4.22	.026546	45
	.835941	2.23	.862234	1.98	.973707	4.22	.026293	44
	.836075	2.23	.862115	1.98	.973960	4.22	.026040	43
	.836209	2.23	.861996	1.98	.974213	4.22	.025787	42
	.836343	2.23	.861877	1.98	.974466	4.23	.025534	41
	.836477	2.23	.861758	2.00	.974720	4.22	.025280	40
	9.836611	2.23	9.861638	1.98	9.974973	4.22	10.025027	39
	.836745	2.22	.861519	1.98	.975226	4.22	.024774	38
	.836878	2.23	.861400	2.00	.975479	4.22	.024521	37
	.837012	2.23	.861280	1.98	.975732	4.22	.024268	36
	.837146	2.22	.861161	2.00	.975985	4.22	.024015	35
	.837279	2.22	.861041	1.98	.976238	4.22	.023762	34
	.837412	2.23	.860922	2.00	.976491	4.22	.023509	33
	.837546	2.22	.860802	2.00	.976744	4.22	.023256	32
	.837679	2.22	.860682	2.00	.976997	4.22	.023003	31
	.837812	2.22	.860562	2.00	.977250	4.22	.022750	30
	9.837945	2.22	9.860442	2.00	9.977503	4.22	10.022497	29
	.838078	2.22	.860322	2.00	.977756	4.22	.022244	28
	.838211	2.22	.860202	2.00	.978009	4.22	.021991	27
	.838344	2.22	.860082	2.00	.978262	4.22	.021738	26
	.838477	2.22	.859962	2.00	.978515	4.22	.021485	25
	.838610	2.20	.859842	2.02	.978768	4.22	.021232	24
	.838742	2.22	.859721	2.00	.979021	4.22	.020979	23
	.838875	2.20	.859601	2.02	.979274	4.22	.020726	22
	.839007	2.22	.859480	2.00	.979527	4.22	.020473	21
	.839140	2.20	.859360	2.02	.979780	4.22	.020220	20
	9.839272	2.20	9.859239	2.00	9.980033	4.22	10.019967	19
	.839404	2.20	.859119	2.02	.980286	4.20	.019714	18
	.839536	2.20	.858998	2.02	.980538	4.22	.019462	17
	.839668	2.20	.858877	2.02	.980791	4.22	.019209	16
	.839800	2.20	.858756	2.02	.981044	4.22	.018956	15
	.839932	2.20	.858635	2.02	.981297	4.22	.018703	14
	.840064	2.20	.858514	2.02	.981550	4.22	.018450	13
	.840196	2.20	.858393	2.02	.981803	4.22	.018197	12
	.840328	2.18	.858272	2.02	.982056	4.22	.017944	11
	.840459	2.20	.858151	2.03	.982309	4.22	.017691	10
	9.840591	2.18	9.858029	2.02	9.982562	4.20	10.017438	9
	.840722	2.20	.857908	2.03	.982814	4.22	.017186	8
	.840854	2.18	.857786	2.02	.983067	4.22	.016933	7
	.840985	2.18	.857665	2.03	.983320	4.22	.016680	6
	.841116	2.18	.857543	2.02	.983573	4.22	.016427	5
	.841247	2.18	.857422	2.03	.983826	4.22	.016174	4
	.841378	2.18	.857300	2.03	.984079	4.22	.015921	3
	.841509	2.18	.857178	2.03	.984332	4.20	.015668	2
	.841640	2.18	.857056	2.03	.984584	4.22	.015416	1
'	9.841771		9.856934		9.984837		10.015163	0
3° Cosine.	D. 1".		Sine.	D. 1".	Cotang.	D. 1".	Tang.	46°

42°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	47°
0′	9.825511	2.33	9.871073	1.88	9.954437	4.23	10.045563	60′
1	.825651	2.33	.870960	1.90	.954691	4.25	.045309	59
2	.825791	2.33	.870846	1.90	.954946	4.23	.045054	58
3	.825931	2.33	.870732	1.90	.955200	4.23	.044800	57
4	.826071	2.33	.870618	1.90	.955454	4.23	.044546	56
5	.826211	2.33	.870504	1.90	.955708	4.22	.044292	55
6	.826351	2.33	.870390	1.90	.955961	4.23	.044039	54
7	.826491	2.33	.870276	1.92	.956215	4.23	.043785	53
8	.826631	2.32	.870161	1.90	.956469	4.23	.043531	52
9	.826770	2.33	.870047	1.90	.956723	4.23	.043277	51
10	.826910	2.32	.869933	1.92	.956977	4.23	.043023	50
11	9.827049	2.33	9.869818	1.90	9.957231	4.23	10.042769	49
12	.827189	2.32	.869704	1.92	.957485	4.23	.042515	48
13	.827328	2.32	.869589	1.92	.957739	4.23	.042261	47
14	.827467	2.32	.869474	1.90	.957993	4.23	.042007	46
15	.827606	2.32	.869360	1.92	.958247	4.22	.041753	45
16	.827745	2.32	.869245	1.92	.958500	4.23	.041500	44
17	.827884	2.32	.869130	1.92	.958754	4.23	.041246	43
18	.828023	2.32	.869015	1.92	.959008	4.23	.040992	42
19	.828162	2.32	.868900	1.92	.959262	4.23	.040738	41
20	.828301	2.30	.868785	1.92	.959516	4.22	.040484	40
21	9.828439	2.32	9.868670	1.92	9.959769	4.23	10.040231	39
22	.828578	2.30	.868555	1.92	.960023	4.23	.039977	38
23	.828716	2.32	.868440	1.93	.960277	4.22	.039723	37
24	.828855	2.30	.868324	1.92	.960530	4.23	.039470	36
25	.828993	2.30	.868209	1.93	.960784	4.23	.039216	35
26	.829131	2.30	.868093	1.92	.961038	4.23	.038962	34
27	.829269	2.30	.867978	1.93	.961292	4.23	.038708	33
28	.829407	2.30	.867862	1.92	.961545	4.23	.038455	32
29	.829545	2.30	.867747	1.93	.961799	4.22	.038201	31
30	.829683	2.30	.867631	1.93	.962052	4.23	.037948	30
31	9.829821	2.30	9.867515	1.93	9.962306	4.23	10.037694	29
32	.829959	2.30	.867399	1.93	.962560	4.22	.037440	28
33	.830097	2.28	.867283	1.93	.962813	4.23	.037187	27
34	.830234	2.30	.867167	1.93	.963067	4.22	.036933	26
35	.830372	2.28	.867051	1.93	.963320	4.23	.036680	25
36	.830509	2.28	.866935	1.93	.963574	4.23	.036426	24
37	.830646	2.30	.866819	1.93	.963828	4.22	.036172	23
38	.830784	2.28	.866703	1.95	.964081	4.23	.035919	22
39	.830921	2.28	.866586	1.93	.964335	4.22	.035665	21
40	.831058	2.28	.866470	1.95	.964588	4.23	.035412	20
41	9.831195	2.28	9.866353	1.93	9.964842	4.22	10.035158	19
42	.831332	2.28	.866237	1.95	.965095	4.23	.034905	18
43	.831469	2.28	.866120	1.93	.965349	4.22	.034651	17
44	.831606	2.27	.866004	1.95	.965602	4.22	.034398	16
45	.831742	2.28	.865887	1.95	.965855	4.23	.034145	15
46	.831879	2.27	.865770	1.95	.966109	4.22	.033891	14
47	.832015	2.28	.865653	1.95	.966362	4.23	.033638	13
48	.832152	2.27	.865536	1.95	.966616	4.22	.033384	12
49	.832288	2.28	.865419	1.95	.966869	4.23	.033131	11
50	.832425	2.27	.865302	1.95	.967123	4.22	.032877	10
51	9.832561	2.27	9.865185	1.95	9.967376	4.22	10.032624	9
52	.832697	2.27	.865068	1.97	.967629	4.23	.032371	8
53	.832833	2.27	.864950	1.95	.967883	4.22	.032117	7
54	.832969	2.27	.864833	1.95	.968136	4.22	.031864	6
55	.833105	2.27	.864716	1.97	.968389	4.23	.031611	5
56	.833241	2.27	.864598	1.95	.968643	4.22	.031357	4
57	.833377	2.25	.864481	1.97	.968896	4.23	.031104	3
58	.833512	2.27	.864363	1.97	.969149	4.23	.030851	2
59	.833648	2.25	.864245	1.97	.969403	4.22	.030597	1
60′	9.833783		9.864127		9.969656		10.030344	0
°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1".	Tang.	42°

0°						1°					
″	′	Vers.	q − 2l		Ex. sec.	″	′	Vers.	q − 2l		Ex. sec.
			9.070						9.070		
0	0	Inf. neg.	120	120	Inf. neg.	3600	0	6.182714	109	175	6.182780
60	1	2.626422	120	120	2.626422	3660	1	.197071	108	177	.197139
120	2	3.228482	120	120	3.228482	3720	2	.211194	108	179	.211264
180	3	.580665	120	120	.580665	3780	3	.225091	108	181	.225164
240	4	3.830542	120	120	3.830542	3840	4	.238770	107	182	.238845
300	5	4.024362	120	120	4.024363	3900	5	.252236	107	184	.252314
360	6	.182725	20	120	.182725	3960	6	.265497	106	186	.265577
420	7	.316618	20	120	.316619	4020	7	.278558	106	188	.278641
480	8	.432602	20	121	.432603	4080	8	.291426	106	191	.291511
540	9	.534907	9	121	.534908	4140	9	.304106	105	193	.304193
600	10	.626422	119	121	.626424	4200	10	.316603	105	195	.316693
660	11	4.709207	119	122	4.709209	4260	11	6.328923	104	197	6.329016
720	12	.784784	119	122	.784787	4320	12	.341071	104	199	.341167
780	13	.854306	119	122	.854312	4380	13	.353052	103	201	.353150
840	14	.918678	119	123	.918681	4440	14	.364869	103	204	.364970
900	15	4.978604	119	123	4.978608	4500	15	.376528	103	206	.376631
960	16	5.034661	119	124	5.034666	4560	16	.388032	102	208	.388138
1020	17	.087319	119	124	.087325	4620	17	.399386	102	211	.399494
1080	18	.136966	119	125	136972	4680	18	.410593	101	213	.410705
1140	19	.183028	119	125	.183935	4740	19	.421657	101	215	.421772
1200	20	.228481	119	126	.228488	4800	20	.432583	100	218	.432700
1260	21	5.270859	118	126	5.270868	4860	21	6.443372	100	220	6.443493
1320	22	.311266	118	127	.311275	4920	22	.454029	099	223	.454153
1380	23	.349876	18	128	.349886	4980	23	.464557	099	225	.464684
1440	24	.386843	118	129	.386854	5040	24	.474959	098	228	.475089
1500	25	.422300	118	129	.422312	5100	25	.485238	098	230	.485371
1560	26	.456367	118	130	.456379	5160	26	.495396	097	233	.495532
1620	27	.489148	18	131	.489161	5220	27	.505438	097	236	.505577
1680	28	.520736	117	132	.520750	5280	28	.515364	096	238	.515506
1740	29	.551216	117	133	.551231	5340	29	.525178	095	241	.525324
1800	30	.580662	117	134	.580679	5400	30	.534882	095	244	.535031
1860	31	5.609143	117	134	5.609160	5460	31	6.544480	094	247	6.544632
1920	32	.636719	17	135	.636738	5520	32	.553972	094	249	.554128
1980	33	.663447	116	136	.663467	5580	33	.563362	093	252	.563521
2040	34	.689377	116	137	.689398	5640	34	.572651	093	255	.572813
2100	35	.714555	116	138	.714577	5700	35	.581842	092	258	.582008
2160	36	.739023	116	140	.739047	5760	36	.590936	092	261	.591106
2220	37	.762821	116	141	.762847	5820	37	.599937	091	264	.600110
2280	38	.785985	115	142	.786012	5880	38	.608845	090	267	.609021
2340	39	.808547	115	143	.808575	5940	39	.617663	090	270	.617843
2400	40	.830537	115	144	.830567	6000	40	.626392	089	273	.626575
2460	41	5.851985	115	145	5.852016	6060	41	6.635034	089	276	6.635221
2520	42	.872015	114	147	.872948	6120	42	.643591	088	279	.643782
2580	43	.893353	114	148	.893387	6180	43	.652064	087	282	.652259
2640	44	.913322	114	149	.913357	6240	44	.660456	087	285	.660655
2700	45	.932841	114	151	.932878	6300	45	.668767	086	289	.668970
2760	46	.951931	113	152	.951970	6360	46	.677000	085	292	.677206
2820	47	.970611	113	154	.970652	6420	47	.685155	085	295	.685365
2880	48	5.988898	113	155	5.988940	6480	48	.693234	084	298	.693448
2940	49	6.006807	112	157	6.006851	6540	49	.701239	083	302	.701457
3000	50	.024355	112	158	.024401	6600	50	.709171	083	305	.709393
3060	51	6.041555	112	160	6.041602	6660	51	6.717030	082	308	6.717257
3120	52	.058421		161	.058470	6720	52	.724820	081	312	.725050
3180	53	.074965		163	.075017	6780	53	.732540	081	315	.732775
3240	54	.091201		164	.091254	6840	54	.740192	080	319	.740431
3300	55	.107138	10	166	.107194	6900	55	.747777	079	322	.748020
3360	56	.122789	10	168	.122846	6960	56	.755297	079	326	.755544
3420	57	.138162	10	169	.138222	7020	57	.762752	078	329	[illegible]
3480	58	.153268	109	171	153330	7080	58	.770144	077	333	[illegible]
3540	59	.168116	109	173	168180	7140	59	.777473	076	337	[illegible]
3600	60	6.182714	109	175	6.182780	7200	60	6.784741	076	340	6.785
″	′					″	′				

44°	Sine.	D. 1".	Cosine.	D. 1".	Tang.	D. 1".	Cotang.	135°
0'	9.841771	2.18	9.856934	2.03	9.984837	4.22	10.015163	60
1	.841902	2.18	.856812	2.03	.985090	4.22	.014910	59
2	.842033	2.17	.856690	2.03	.985343	4.22	.014657	58
3	.842163	2.18	.856568	2.03	.985596	4.20	.014404	57
4	.842294	2.17	.856446	2.05	.985848	4.22	.014152	56
5	.842424	2.18	.856323	2.03	.986101	4.22	.013899	55
6	.842555	2.17	.856201	2.05	.986354	4.22	.013646	54
7	.842685	2.17	.856078	2.03	.986607	4.22	.013393	53
8	.842815	2.18	.855956	2.05	.986860	4.20	.013140	52
9	.842946	2.17	.855833	2.03	.987112	4.22	.012888	51
10	.843076	2.17	.855711	2.05	.987365	4.22	.012635	50
11	9.843206	2.17	9.855588	2.05	9.987618	4.22	10.012382	49
12	.843336	2.17	.855465	2.05	.987871	4.20	.012129	48
13	.843466	2.15	.855342	2.05	.988123	4.22	.011877	47
14	.843595	2.17	.855219	2.05	.988376	4.22	.011624	46
15	.843725	2.17	.855096	2.05	.988629	4.22	.011371	45
16	.843855	2.15	.854973	2.05	.988882	4.20	.011118	44
17	.843984	2.17	.854850	2.05	.989134	4.22	.010866	43
18	.844114	2.15	.854727	2.07	.989387	4.22	.010613	42
19	.844243	2.15	.854603	2.05	.989640	4.22	.010360	41
20	.844372	2.17	.854480	2.07	.989893	4.20	.010107	40
21	9.844502	2.15	9.854356	2.05	9.990145	4.22	10.009855	39
22	.844631	2.15	.854233	2.07	.990398	4.22	.009602	38
23	.844760	2.15	.854109	2.05	.990651	4.20	.009349	37
24	.844889	2.15	.853986	2.07	.990903	4.22	.009097	36
25	.845018	2.15	.853862	2.07	.991156	4.22	.008844	35
26	.845147	2.15	.853738	2.07	.991409	4.22	.008591	34
27	.845276	2.15	.853614	2.07	.991662	4.20	.008338	33
28	.845405	2.13	.853490	2.07	.991914	4.22	.008086	32
29	.845533	2.15	.853366	2.07	.992167	4.22	.007833	31
30	.845662	2.13	.853242	2.07	.992420	4.20	.007580	30
31	9.845790	2.15	9.853118	2.07	9.992672	4.22	10.007328	29
32	.845919	2.13	.852994	2.08	.992925	4.22	.007075	28
33	.846047	2.13	.852869	2.07	.993178	4.22	.006822	27
34	.846175	2.15	.852745	2.08	.993431	4.20	.006569	26
35	.846304	2.13	.852620	2.07	.993683	4.22	.006317	25
36	.846432	2.13	.852496	2.08	.993936	4.22	.006064	24
37	.846560	2.13	.852371	2.07	.994189	4.20	.005811	23
38	.846688	2.13	.852247	2.08	.994441	4.22	.005559	22
39	.846816	2.13	.852122	2.08	.994694	4.22	.005306	21
40	.846944	2.12	.851997	2.08	.994947	4.20	.005053	20
41	9.847071	2.13	9.851872	2.08	9.995199	4.22	10.004801	19
42	.847199	2.13	.851747	2.08	.995452	4.22	.004548	18
43	.847327	2.12	.851622	2.08	.995705	4.20	.004295	17
44	.847454	2.13	.851497	2.08	.995957	4.22	.004043	16
45	.847582	2.12	.851372	2.10	.996210	4.22	.003790	15
46	.847709	2.12	.851246	2.08	.996463	4.20	.003537	14
47	.847836	2.13	.851121	2.08	.996715	4.22	.003285	13
48	.847964	2.12	.850996	2.10	.996968	4.22	.003032	12
49	.848091	2.12	.850870	2.08	.997221	4.20	.002779	11
50	.848218	2.12	.850745	2.10	.997473	4.22	.002527	10
51	9.848345	2.12	9.850619	2.10	9.997726	4.22	10.002274	9
52	.848472	2.12	.850493	2.08	.997979	4.20	.002021	8
53	.848599	2.12	.850368	2.10	.998231	4.22	.001769	7
54	.848726	2.10	.850242	2.10	.998484	4.22	.001516	6
55	.848852	2.12	.850116	2.10	.998737	4.20	.001263	5
56	.848979	2.12	.849990	2.10	.998989	4.22	.001011	4
57	.849106	2.10	.849864	2.10	.999242	4.22	.000758	3
58	.849232	2.12	.849738	2.12	.999495	4.20	.000505	2
59	.849359	2.10	.849611	2.10	.999747	4.22	.000253	1
60	9.849485		9 849485		10.000000		10.000000	0
°	Cosine.	D. 1".	Sine.	D. 1".	Cotang.	D. 1"	Tang.	4

4°					5°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	7.386668	60.17	7.387728	60.32	0	7.580389	48.15	7.582045	48.33
1	.390278	59.93	.391347	60.07	1	.583278	47.98	.584945	48.17
2	.393874	59.67	.394951	59.82	2	.586157	47.82	.587835	48.00
3	.397454	59.43	.398540	59.57	3	.589026	47.67	.590715	47.87
4	.401020	59.18	.402114	59.33	4	.591886	47.52	.593587	47.70
5	.404571	58.93	.405674	59.10	5	.594737	47.35	.596449	47.53
6	.408107	58.70	.409220	58.85	6	.597578	47.20	.599301	47.38
7	.411629	58.47	.412751	58.62	7	.600410	47.05	.602144	47.25
8	.415137	58.23	.416268	58.38	8	.603233	46.90	.604979	47.08
9	.418631	58.00	.419771	58.15	9	.606047	46.73	.607804	46.92
10	.422111	57.77	.423260	57.92	10	.608851	46.60	.610619	46.78
11	7.425577	57.53	7.426735	57.70	11	7.611647	46.43	7.613426	46.63
12	.429029	57.30	.430197	57.45	12	.614433	46.30	.616224	46.48
13	.432467	57.08	.433644	57.25	13	.617211	46.15	.619013	46.35
14	.435892	56.85	.437079	57.00	14	.619980	45.98	.621794	46.18
15	.439303	56.63	.440499	56.80	15	.622739	45.87	.624565	46.05
16	.442701	56.42	.443907	56.57	16	.625491	45.70	.627328	45.90
17	.446086	56.20	.447301	56.35	17	.628233	45.57	.630082	45.75
18	.449458	55.97	.450682	56.13	18	.630967	45.42	.632827	45.62
19	.452816	55.77	.454050	55.92	19	.633692	45.28	.635564	45.48
20	.456162	55.55	.457405	55.72	20	.636409	45.13	.638293	45.33
21	7.459495	55.33	7.460748	55.48	21	7.639117	44.98	7.641013	45.18
22	.462815	55.12	.464077	55.28	22	.641816	44.87	.643724	45.07
23	.466122	54.92	.467394	55.08	23	.644508	44.72	.646428	44.90
24	.469417	54.70	.470699	54.87	24	.647191	44.57	.649122	44.78
25	.472699	54.50	.473991	54.65	25	.649865	44.45	.651809	44.65
26	.475969	54.28	.477270	54.47	26	.652532	44.30	.654488	44.50
27	.479226	54.10	.480538	54.25	27	.655190	44.17	.657158	44.37
28	.482472	53.88	.483793	54.05	28	.657840	44.05	.659820	44.23
29	.485705	53.70	.487036	53.85	29	.660483	43.90	.662474	44.12
30	.488927	53.48	.490267	53.67	30	.663117	43.77	.665121	43.97
31	7.492136	53.28	7.493487	53.45	31	7.665743	43.63	7.667759	43.83
32	.495333	53.10	.496694	53.27	32	.668361	43.50	.670389	43.72
33	.498519	52.90	.499890	53.07	33	.670971	43.38	.673012	43.57
34	.501693	52.72	.503074	52.88	34	.673574	43.23	.675626	43.45
35	.504856	52.52	.506247	52.68	35	.676168	43.12	.678233	43.33
36	.508007	52.33	.509408	52.50	36	.678755	42.98	.680833	43.18
37	.511147	52.13	.512558	52.32	37	.681334	42.87	.683424	43.07
38	.514275	51.95	.515697	52.12	38	.683906	42.73	.686008	42.95
39	.517392	51.77	.518824	51.93	39	.686470	42.60	.688585	42.82
40	.520498	51.58	.521940	51.77	40	.689026	42.48	.691154	42.68
41	7 523593	51.40	7.325046	51.57	41	7.691575	42.35	7.693715	42.57
42	526677	51.22	.528140	51.38	42	.694116	42.23	.696269	42.43
43	529750	51.03	.531223	51.22	43	.696650	42.12	.698815	42.33
44	.532812	50.85	.534296	51.02	44	.699177	41.98	.701355	42.20
45	.535863	50.68	.537357	50.85	45	.701696	41.87	.703887	42.07
46	.538904	50.50	.540408	50.68	46	.704208	41.73	.706411	41.97
47	.541934	50.32	.543449	50.50	47	.706712	41.63	.708929	41.83
48	.544953	50.15	.546479	50.33	48	.709210	41.50	.711439	41.73
49	.547962	49.98	.549499	50.15	49	.711700	41.38	.713942	41.60
50	.550961	49.80	.552508	49.98	50	.714183	41.27	.716438	41.48
51	7.553949	49.63	7.555507	49.80	51	7.716659	41.15	7.718927	41.37
52	.556927	49.47	.558495	49.63	52	.719128	41.03	.721409	41.25
53	.559895	49.28	.561474	49.47	53	.721590	40.92	.723884	41.13
54	.562852	49.13	.564442	49.32	54	.724045	40.80	.726352	41.02
55	.565800	48.95	.567401	49.13	55	.726493	40.68	.728813	40.90
56	.568737	48.80	.570349	48.98	56	.728934	40.57	.731267	40.78
57	.571665	48.63	.573288	48.82	57	.731368	40.47	.733714	40.68
58	.574583	48.47	.576217	48.65	58	.733796	40.33	.736155	40.5
59	.577491	48.30	.579136	48.48	59	.736216	40.23	.738589	40.
60	7.580389	48.15	7.582045	48.33	60	7.738630	40.13	7.741016	40

6°					7°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	7.738630	40.13	7.741016	40.33	0	7.872381	34.38	7.875630	34.63
1	.741038	40.00	.743436	40.23	1	.874444	34.30	.877708	34.57
2	.743438	39.90	.745850	40.13	2	.876502	34.22	.879782	34.48
3	.745832	39.78	.748258	40.00	3	.878555	34.13	.881851	34.40
4	.748219	39.68	.750658	39.90	4	.880603	34.07	.883915	34.32
5	.750600	39.57	.753052	39.80	5	.882647	33.98	.885974	34.25
6	.752974	39.47	.755440	39.68	6	.884686	33.90	.888029	34.15
7	.755342	39.35	.757821	39.58	7	.886720	33.82	.890078	34.08
8	.757703	39.25	.760196	39.48	8	.888749	33.73	.892123	34.02
9	.760058	39.13	.762565	39.37	9	.890773	33.67	.894164	33.92
10	.762406	39.05	.764927	39.25	10	.892793	33.58	.896199	33.85
11	7.764749	38.92	7.767282	39.17	11	7.894808	33.50	7.898230	33.77
12	.767084	38.83	.769632	39.05	12	.896818	33.43	.900256	33.70
13	.769414	38.72	.771975	38.95	13	.898824	33.35	.902278	33.63
14	.771737	38.62	.774312	38.85	14	.900825	33.27	.904295	33.53
15	.774054	38.52	.776643	38.75	15	.902821	33.20	.906307	33.47
16	.776365	38.42	.778968	38.63	16	.904813	33.12	.908315	33.40
17	.778670	38.30	.781286	38.55	17	.906800	33.05	.910319	33.30
18	.780968	38.22	.783599	38.43	18	.908783	32.97	.912317	33.25
19	.783261	38.10	.785905	38.35	19	.910761	32.90	.914312	33.17
20	.785547	38.02	.788206	38.23	20	.912735	32.82	.916302	33.08
21	7.787828	37.90	7.790500	38.15	21	7.914704	32.73	7.918287	33.02
22	.790102	37.82	.792789	38.03	22	.916668	32.68	.920268	32.95
23	.792371	37.70	.795071	37.95	23	.918629	32.58	.922245	32.87
24	.794633	37.62	.797348	37.85	24	.920584	32.53	.924217	32.78
25	.796890	37.52	.799619	37.75	25	.922536	32.45	.926184	32.73
26	.799141	37.40	.801884	37.65	26	.924483	32.37	.928148	32.65
27	.801385	37.33	.804143	37.57	27	.926425	32.32	.930107	32.58
28	.803625	37.22	.806397	37.45	28	.928364	32.22	.932062	32.50
29	.805858	37.13	.808644	37.37	29	.930297	32.17	.934012	32.43
30	.808086	37.03	.810886	37.28	30	.932227	32.08	.935958	32.37
31	7.810308	36.93	7.813123	37.17	31	7.934152	32.02	7.937900	32.30
32	.812524	36.83	.815353	37.08	32	.936073	31.95	.939838	32.23
33	.814734	36.75	.817578	37.00	33	.937990	31.88	.941772	32.15
34	.816939	36.67	.819798	36.90	34	.939903	31.80	.943701	32.08
35	.819139	36.55	.822012	36.80	35	.941811	31.73	.945626	32.02
36	.821332	36.48	.824220	36.72	36	.943715	31.67	.947547	31.95
37	.823521	36.37	.826423	36.62	37	.945615	31.60	.949464	31.87
38	.825703	36.28	.828620	36.53	38	.947511	31.52	.951376	31.82
39	.827880	36.20	.830812	36.45	39	.949402	31.47	.953285	31.73
40	.830052	36.10	.832999	36.35	40	.951290	31.38	.955189	31.68
41	7.832218	36.02	7.835180	36.27	41	7.953173	31.32	7.957090	31.60
42	.834379	35.93	.837356	36.17	42	.955052	31.27	.958986	31.53
43	.836535	35.83	.839526	36.08	43	.956928	31.18	.960878	31.48
44	.838685	35.75	.841691	36.00	44	.958799	31.12	.962767	31.40
45	.840830	35.65	.843851	35.90	45	.960666	31.05	.964651	31.33
46	.842969	35.58	.846005	35.83	46	.962529	30.98	.966531	31.28
47	.845104	35.48	.848155	35.73	47	.964388	30.92	.968408	31.20
48	.847233	35.40	.850299	35.63	48	.966243	30.85	.970280	31.13
49	.849357	35.30	.852437	35.57	49	.968094	30.78	.972148	31.08
50	.851475	35.23	.854571	35.48	50	.969941	30.73	.974013	31.02
51	7.853589	35.13	7.856700	35.38	51	7.971785	30.65	7.975874	30.93
52	.855697	35.05	.858823	35.32	52	.973624	30.58	.977730	30.88
53	.857800	34.97	.860942	35.22	53	.975459	30.53	.979583	30.82
54	.859898	34.88	.863055	35.13	54	.977291	30.45	.981432	30.75
55	.861991	34.80	.865163	35.05	55	.979118	30.40	.983277	30.70
56	.864079	34.72	.867266	34.98	56	.980942	30.33	.985119	30.62
57	*.866162*	34.63	.869365	34.88	57	.982762	30.27	.986956	30.57
58	*.868240*	*34.55*	.871458	34.80	58	.984578	30.22	.988790	30.50
59	*.870313*	*34.47*	.873546	34.73	59	.986391	30.13	.990620	30.43
60	*7.872381*	*34.38*	7.875630	34.63	60	7.988199	30.08	7.992446	30.35

	4°					5°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	7.386668	60.17	7.387728	60.32	0	7.580389	48.15	7.582045	48.33
1	.390278	59.93	.391347	60.07	1	.583278	47.98	.584945	48.17
2	.393874	59.67	.394951	59.82	2	.586157	47.82	.587835	48.00
3	.397454	59.43	.398540	59.57	3	.589026	47.67	.590715	47.87
4	.401020	59.18	.402114	59.33	4	.591886	47.52	.593587	47.70
5	.404571	58.93	.405674	59.10	5	.594737	47.35	.596449	47.53
6	.408107	58.70	.409220	58.85	6	.597578	47.20	.599301	47.38
7	.411629	58.47	.412751	58.62	7	.600410	47.05	.602144	47.25
8	.415137	58.23	.416268	58.38	8	.603233	46.90	.604979	47.08
9	.418631	58.00	.419771	58.15	9	.606047	46.73	.607804	46.92
10	.422111	57.77	.423260	57.92	10	.608851	46.60	.610619	46.78
11	7.425577	57.53	7.426735	57.70	11	7.611647	46.43	7.613426	46.63
12	.429029	57.30	.430197	57.45	12	.614433	46.30	.616224	46.48
13	.432467	57.08	.433644	57.25	13	.617211	46.15	.619013	46.35
14	.435892	56.85	.437079	57.00	14	.619980	45.98	.621794	46.18
15	.439303	56.63	.440499	56.80	15	.622739	45.87	.624565	46.05
16	.442701	56.42	.443907	56.57	16	.625491	45.70	.627328	45.90
17	.446086	56.20	.447301	56.35	17	.628233	45.57	.630082	45.75
18	.449458	55.97	.450682	56.13	18	.630967	45.42	.632827	45.62
19	.452816	55.77	.454050	55.92	19	.633692	45.28	.635564	45.48
20	.456162	55.55	.457405	55.72	20	.636409	45.13	.638293	45.33
21	7.459495	55.33	7.460748	55.48	21	7.639117	44.98	7.641013	45.18
22	.462815	55.12	.464077	55.28	22	.641816	44.87	.643724	45.07
23	.466122	54.92	.467394	55.08	23	.644508	44.72	.646428	44.90
24	.469417	54.70	.470699	54.87	24	.647191	44.57	.649122	44.78
25	.472699	54.50	.473991	54.65	25	.649865	44.45	.651809	44.65
26	.475969	54.28	.477270	54.47	26	.652532	44.30	.654488	44.50
27	.479226	54.10	.480538	54.25	27	.655190	44.17	.657158	44.37
28	.482472	53.88	.483793	54.05	28	.657840	44.05	.659820	44.23
29	.485705	53.70	.487036	53.85	29	.660483	43.90	.662474	44.12
30	.488927	53.48	.490267	53.67	30	.663117	43.77	.665121	43.97
31	7.492136	53.28	7.493487	53.45	31	7.665743	43.63	7.667759	43.83
32	.495333	53.10	.496694	53.27	32	.668361	43.50	.670389	43.72
33	.498519	52.90	.499890	53.07	33	.670971	43.38	.673012	43.57
34	.501693	52.72	.503074	52.88	34	.673574	43.23	.675626	43.45
35	.504856	52.52	.506247	52.68	35	.676168	43.12	.678233	43.33
36	.508007	52.33	.509408	52.50	36	.678755	42.98	.680833	43.18
37	.511147	52.13	.512558	52.32	37	.681334	42.87	.683424	43.07
38	.514275	51.95	.515697	52.12	38	.683906	42.73	.686008	42.95
39	.517392	51.77	.518824	51.93	39	.686470	42.60	.688585	42.82
40	.520498	51.58	.521940	51.77	40	.689026	42.48	.691154	42.68
41	7 523593	51.40	7.525046	51.57	41	7.691575	42.35	7.693715	42.57
42	526677	51.22	.528140	51.38	42	.694116	42.23	.696269	42.43
43	529750	51.03	.531223	51.22	43	.696650	42.12	.698815	42.33
44	.532812	50.85	.534296	51.02	44	.699177	41.98	.701355	42.20
45	.535863	50.68	.537357	50.85	45	.701696	41.87	.703887	42.07
46	.538904	50.50	.540408	50.68	46	.704208	41.73	.706411	41.97
47	.541934	50.32	.543449	50.50	47	.706712	41.63	.708929	41.83
48	.544953	50.15	.546479	50.33	48	.709210	41.50	.711439	41.72
49	.547962	49.98	.549499	50.15	49	.711700	41.38	.713942	41.60
50	.550961	49.80	.552508	49.98	50	.714183	41.27	.716438	41.48
51	7.553949	49.63	7.555507	49.80	51	7.716659	41.15	7.718927	41.37
52	.556927	49.47	.558495	49.65	52	.719128	41.03	.721409	41.25
53	.559895	49.28	.561474	49.47	53	.721590	40.92	.723884	41.13
54	.562852	49.13	.564442	49.32	54	.724045	40.80	.726352	41.02
55	.565800	48.95	.567401	49.13	55	.726493	40.68	.728813	40.90
56	.568737	48.80	.570349	48.98	56	.728934	40.57	.731267	40.78
57	.571665	48.63	.573288	48.82	57	.731368	40.47	.733714	40.6
58	.574583	48.47	.576217	48.65	58	.733796	40.33	.736155	40.
59	.577491	48.30	.579136	48.48	59	.736216	40.23	.738589	4
60	7.580389	48.15	7.582045	48.33	60	7.738630	40.13	7.741018	4

6°					7°			
'	Vers.	D. 1".	Ex. sec.	D. 1".	'	Vers.	D. 1".	Ex. sec.
0	7.738630	40.13	7.741016	40.33	0	7.872381	34.38	7.875630
1	.741038	40.00	.743436	40.23	1	.874444	34.30	.877708
2	.743438	39.90	.745850	40.13	2	.876502	34.22	.879782
3	.745832	39.78	.748258	40.00	3	.878555	34.13	.881851
4	.748219	39.68	.750658	39.90	4	.880603	34.07	.883915
5	.750600	39.57	.753052	39.80	5	.882647	33.98	.885974
6	.752974	39.47	.755440	39.68	6	.884686	33.90	.888029
7	.755342	39.35	.757821	39.58	7	.886720	33.82	.890078
8	.757703	39.25	.760196	39.48	8	.888749	33.73	.892123
9	.760058	39.13	.762565	39.37	9	.890773	33.67	.894164
10	.762406	39.05	.764927	39.25	10	.892798	33.58	.896199
11	7.764749	38.92	7.767282	39.17	11	7.894808	33.50	7.898230
12	.767084	38.83	.769632	39.05	12	.896818	33.43	.900256
13	.769414	38.72	.771975	38.95	13	.898824	33.35	.902278
14	.771737	38.62	.774312	38.85	14	.900825	33.27	.904295
15	.774054	38.52	.776643	38.75	15	.902821	33.20	.906307
16	.776365	38.42	.778968	38.63	16	.904813	33.12	.908315
17	.778670	38.30	.781286	38.55	17	.906800	33.05	.910319
18	.780968	38.22	.783599	38.43	18	.908783	32.97	.912317
19	.783261	38.10	.785905	38.35	19	.910761	32.90	.914312
20	.785547	38.02	.788206	38.23	20	.912735	32.82	.916302
21	7.787828	37.90	7.790500	38.15	21	7.914704	32.73	7.918287
22	.790102	37.82	.792789	38.03	22	.916668	32.68	.920268
23	.792371	37.70	.795071	37.95	23	.918629	32.58	.922245
24	.794633	37.62	.797348	37.85	24	.920584	32.53	.924217
25	.796890	37.52	.799619	37.75	25	.922536	32.45	.926184
26	.799141	37.40	.801884	37.65	26	.924483	32.37	.928148
27	.801385	37.33	.804143	37.57	27	.926425	32.32	.930107
28	.803625	37.22	.806397	37.45	28	.928364	32.22	.932062
29	.805858	37.13	.808644	37.37	29	.930297	32.17	.934012
30	.808086	37.03	.810886	37.28	30	.932227	32.08	.935958
31	7.810308	36.93	7.813123	37.17	31	7.934152	32.02	7.937900
32	.812524	36.83	.815353	37.08	32	.936073	31.95	.939828
33	.814734	36.75	.817578	37.00	33	.937990	31.88	.941772
34	.816939	36.67	.819798	36.90	34	.939903	31.80	.943701
35	.819139	36.55	.822012	36.80	35	.941811	31.73	.945626
36	.821332	36.48	.824220	36.72	36	.943715	31.67	.947547
37	.823521	36.37	.826423	36.62	37	.945615	31.60	.949464
38	.825703	36.28	.828620	36.53	38	.947511	31.52	.951376
39	.827880	36.20	.830812	36.45	39	.949402	31.47	.953285
40	.830052	36.10	.832999	36.35	40	.951290	31.38	.955189
41	7.832218	36.02	7.835180	36.27	41	7.953173	31.32	7.957090
42	.834379	35.93	.837356	36.17	42	.955052	31.27	.958986
43	.836535	35.83	.839526	36.08	43	.956928	31.18	.960878
44	.838685	35.75	.841691	36.00	44	.958799	31.12	.962767
45	.840830	35.65	.843851	35.90	45	.960666	31.05	.964651
46	.842969	35.58	.846005	35.83	46	.962529	30.98	.966531
47	.845104	35.48	.848155	35.73	47	.964388	30.92	.968408
48	.847233	35.40	.850299	35.63	48	.966243	30.85	.970280
49	.849357	35.30	.852437	35.57	49	.968094	30.78	.972148
50	.851475	35.23	.854571	35.48	50	.969941	30.73	.974013
51	7.853589	35.13	7.856700	35.38	51	7.971785	30.65	7.975874
52	.855697	35.05	.858823	35.32	52	.973624	30.58	.977730
53	.857800	34.97	.860942	35.22	53	.975459	30.53	.979583
54	.859898	34.88	.863055	35.13	54	.977291	30.45	.981432
55	.861991	34.80	.865163	35.05	55	.979118	30.40	.983277
[illegible]	.864079	34.72	.867266	34.98	56	.980942	30.33	.985119
[illegible]	.866162	34.63	.869365	34.88	57	.982762	30.27	.986956
[illegible]	.868240	34.55	.871458	34.80	58	.984578	30.22	.988790
	870313	34.47	.873546	34.73	59	.986391	30.13	.990622
	872381	34.38	7.875630	34.63	60	7.988193	30.08	7.99244

	8°					9°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	7.988199	30.08	7.992446	30.38	0	8.090317	26.72	8.095697	27.05
1	.990004	30.02	.994269	30.32	1	.091920	26.68	.097320	27.02
2	.991805	29.95	.996088	30.25	2	.093521	26.63	.098941	26.97
3	.993602	29.88	.997903	30.18	3	.095119	26.58	.100559	26.92
4	.995395	29.83	7.999714	30.13	4	.096714	26.52	.102174	26.87
5	.997185	29.77	8.001522	30.07	5	.098305	26.48	.103786	26.82
6	7.998971	29.72	.003326	30.00	6	.099894	26.43	.105395	26.77
7	8.000754	29.63	.005126	29.95	7	.101480	26.40	.107001	26.73
8	.002532	29.60	.006923	29.88	8	.103064	26.33	.108605	26.67
9	.004308	29.52	.008716	29.83	9	.104644	26.28	.110205	26.63
10	.006079	29.47	.010506	29.77	10	.106221	26.25	.111803	26.58
11	8.007847	29.40	8.012292	29.70	11	8.107796	26.18	8.113398	26.53
12	.009611	29.35	.014074	29.65	12	.109367	26.15	.114990	26.48
13	.011372	29.28	.015853	29.58	13	.110936	26.10	.116579	26.45
14	.013129	29.22	.017628	29.53	14	.112502	26.05	.118166	26.38
15	.014882	29.17	.019400	29.47	15	.114065	26.00	.119749	26.35
16	.016632	29.10	.021168	29.42	16	.115625	25.95	.121330	26.30
17	.018378	29.05	.022933	29.35	17	.117182	25.92	.122908	26.25
18	.020121	29.00	.024694	29.30	18	.118737	25.87	.124483	26.22
19	.021861	28.93	.026452	29.23	19	.120289	25.82	.126056	26.17
20	.023597	28.87	.028206	29.18	20	.121838	25.77	.127626	26.12
21	8.025329	28.82	8.029957	29.13	21	8.123384	25.72	8.129193	26.07
22	.027058	28.75	.031705	29.07	22	.124927	25.68	.130757	26.02
23	.028783	28.70	.033449	29.00	23	.126468	25.63	.132318	25.98
24	.030505	28.65	.035189	28.97	24	.128006	25.58	.133877	25.93
25	.032224	28.58	.036927	28.90	25	.129541	25.55	.135433	25.90
26	.033939	28.53	.038661	28.83	26	.131074	25.50	.136987	25.85
27	.035651	28.47	.040391	28.78	27	.132604	25.45	.138538	25.80
28	.037359	28.42	.042118	28.73	28	.134131	25.40	.140086	25.75
29	.039064	28.37	.043842	28.68	29	.135655	25.37	.141631	25.72
30	.040766	28.30	.045563	28.62	30	.137177	25.32	.143174	25.67
31	8.042464	28.25	8.047280	28.57	31	8.138696	25.27	8.144714	25.63
32	.044159	28.20	.048994	28.50	32	.140212	25.23	.146252	25.58
33	.045851	28.13	.050704	28.47	33	.141726	25.18	.147787	25.53
34	.047539	28.08	.052412	28.40	34	.143237	25.13	.149319	25.50
35	.049224	28.03	.054116	28.35	35	.144745	25.10	.150849	25.45
36	.050906	27.98	.055817	28.28	36	.146251	25.05	.152376	25.40
37	.052585	27.92	.057514	28.25	37	.147754	25.02	.153900	25.37
38	.054260	27.87	.059209	28.18	38	.149255	24.95	.155422	25.33
39	.055932	27.82	.060900	28.13	39	.150752	24.93	.156942	25.27
40	.057601	27.75	.062588	28.08	40	.152248	24.88	.158458	25.25
41	8.059266	27.72	8.064273	28.03	41	8.153741	24.83	8.159973	25.18
42	.060929	27.65	.065955	27.97	42	.155231	24.78	.161484	25.17
43	.062588	27.60	.067633	27.93	43	.156718	24.75	.162994	25.10
44	.064244	27.55	.069309	27.87	44	.158203	24.72	.164500	25.07
45	.065897	27.48	.070981	27.82	45	.159686	24.67	.166004	25.03
46	.067546	27.45	.072650	27.77	46	.161166	24.62	.167506	24.98
47	.069193	27.38	.074316	27.72	47	.162643	24.58	.169005	24.95
48	.070836	27.33	.075979	27.67	48	.164118	24.53	.170502	24.90
49	.072476	27.30	.077639	27.60	49	.165590	24.50	.171996	24.87
50	.074114	27.23	.079295	27.57	50	.167060	24.45	.173488	24.82
51	8.075748	27.18	8.080949	27.52	51	8.168527	24.42	8.174977	24.78
52	.077379	27.13	.082600	27.45	52	.169992	24.37	.176464	24.73
53	.079007	27.07	.084247	27.42	53	.171454	24.33	.177948	24.70
54	.080631	27.03	.085892	27.37	54	.172914	24.30	.179430	24.65
55	.082253	26.98	.087534	27.30	55	.174372	24.25	.180909	24.62
56	.083872	26.93	.089172	27.27	56	.175827	24.20	.182386	24.5
57	.085488	26.87	.090808	27.20	57	.177279	24.17	.183861	24.
58	.087100	26.83	.092440	27.17	58	.178729	24.13	.185333	2
59	.088710	26.78	.094070	27.12	59	.180177	24.08	.186803	
60	8.090317	26.72	8.095697	27.05	60	8.181622	24.05	8.188271	

	10°					11°		
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.
0	8.181622	24.05	8.188271	24.42	0	8.264176	21.85	8.272229
1	.183065	24.00	.189736	24.37	1	.265487	21.82	.273565
2	.184505	23.97	.191198	24.35	2	.266796	21.78	.274898
3	.185943	23.93	.192659	24.30	3	.268103	21.75	.276230
4	.187379	23.88	.194117	24.25	4	.269408	21.72	.277560
5	.188812	23.85	.195572	24.22	5	.270711	21.68	.278888
6	.190243	23.80	.197025	24.18	6	.272012	21.65	.280213
7	.191671	23.77	.198476	24.15	7	.273311	21.62	.281537
8	.193097	23.73	.199925	24.10	8	.274608	21.58	.282859
9	.194521	23.68	.201371	24.07	9	.275903	21.57	.284179
10	.195942	23.65	.202815	24.03	10	.277197	21.52	.285498
11	8.197361	23.62	8.204257	23.98	11	8.278488	21.48	8.286814
12	.198778	23.57	.205696	23.95	12	.279777	21.47	.288128
13	.200192	23.53	.207133	23.92	13	.281065	21.42	.289441
14	.201604	23.50	.208568	23.88	14	.282350	21.40	.290751
15	.203014	23.45	.210001	23.83	15	.283634	21.37	.292060
16	.204421	23.42	.211431	23.80	16	.284916	21.33	.293367
17	.205826	23.38	.212859	23.77	17	.286196	21.28	.294672
18	.207229	23.35	.214285	23.72	18	.287473	21.27	.295975
19	.208630	23.30	.215708	23.70	19	.288749	21.25	.297276
20	.210028	23.27	.217130	23.65	20	.290024	21.20	.298576
21	8.211424	23.23	8.218549	23.62	21	8.291296	21.17	8.299873
22	.212818	23.18	.219966	23.57	22	.292566	21.15	.301169
23	.214209	23.17	.221380	23.55	23	.293835	21.10	.302463
24	.215599	23.12	.222793	23.50	24	.295101	21.08	.303755
25	.216986	23.08	.224203	23.47	25	.296366	21.05	.305045
26	.218371	23.03	.225611	23.43	26	.297629	21.02	.306334
27	.219753	23.00	.227017	23.40	27	.298890	20.98	.307620
28	.221133	22.98	.228421	23.35	28	.300149	20.95	.308905
29	.222512	22.93	.229822	23.32	29	.301406	20.93	.310188
30	.223888	22.88	.231221	23.30	30	.302662	20.90	.311469
31	8.225261	22.87	8.232619	23.25	31	8.303916	20.85	8.312749
32	.226633	22.82	.234014	23.22	32	.305167	20.85	.314026
33	.228002	22.78	.235407	23.17	33	.306418	20.80	.315302
34	.229369	23.77	.236797	23.15	34	.307666	20.77	.316576
35	.230735	22.70	.238186	23.10	35	.308912	20.75	.317849
36	.232097	22.68	.239572	23.08	36	.310157	20.72	.319119
37	.233458	22.65	.240957	23.03	37	.311400	20.68	.320388
38	.234817	22.60	.242339	23.00	38	.312641	20.65	.321655
39	.236173	22.57	.243719	22.97	39	.313880	20.62	.322920
40	.237527	22.55	.245097	22.93	40	.315117	20.60	.324183
41	8.238880	22.50	8.246473	22.90	41	8.316353	20.57	8.325445
42	.240230	22.47	.247847	22.87	42	.317587	20.53	.326705
43	.241578	22.43	.249019	22.83	43	.318819	20.50	.327964
44	.242924	22.38	.250389	22.80	44	.320049	20.48	.329220
45	.244267	22.37	.251957	22.75	45	.321278	20.45	.330475
46	.245609	22.32	.253322	22.73	46	.322505	20.42	.331728
47	.246948	22.30	.254686	22.68	47	.323730	20.38	.332980
48	.248286	22.25	.256047	22.67	48	.324953	20.37	.334229
49	.249621	22.23	.257407	22.62	49	.326175	20.33	.335477
50	.250955	22.18	.258764	22.60	50	.327395	20.30	.336724
51	8.252286	22.15	8.260120	22.55	51	8.328613	20.27	8.337968
52	.253615	22.12	.261473	22.53	52	.329829	20.25	.339211
53	.254942	22.10	.262825	22.48	53	.331044	20.22	.340453
54	.256268	22.05	.264174	22.47	54	.332257	20.18	.341692
55	.257591	22.02	.265522	22.42	55	.333468	20.17	.342930
56	.258912	21.98	.266867	22.40	56	.334678	20.13	.344166
	.260231	21.95	.268211	22.35	57	.335886	20.10	.345401
	.261548	21.93	.269552	22.33	58	.337092	20.07	.3466
	.262863	21.88	.270892	22.28	59	.338296	20.05	.3478
	8.264176	21.85	8.272229	22.27	60	8.339499	20.02	8.349

12°					13°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	8.339499	20.02	8.349095	20.47	0	8.408748	18.47	8.420024	18.95
1	.340700	20.00	.350323	20.43	1	.409856	18.43	.421161	18.93
2	.341900	19.95	.351549	20.42	2	.410962	18.42	.422297	18.90
3	.343097	19.95	.352774	20.38	3	.412067	18.40	.423431	18.88
4	.344294	19.90	.353997	20.35	4	.413171	18.38	.424564	18.87
5	.345488	19.88	.355218	20.33	5	.414274	18.35	.425696	18.83
6	.346681	19.85	.356438	20.30	6	.415375	18.32	.426826	18.82
7	.347872	19.82	.357656	20.28	7	.416474	18.30	.427955	18.80
8	.349061	19.80	.358873	20.25	8	.417572	18.28	.429083	18.77
9	.350249	19.77	.360088	20.22	9	.418669	18.25	.430209	18.75
10	.351435	19.75	.361301	20.20	10	.419764	18.23	.431334	18.73
11	8.352620	19.72	8.362513	20.18	11	8.420858	18.22	8.432458	18.70
12	.353803	19.68	.363724	20.13	12	.421951	18.18	.433580	18.67
13	.354984	19.67	.364932	20.12	13	.423042	18.17	.434700	18.67
14	.356164	19.63	.366139	20.10	14	.424132	18.13	.435820	18.63
15	.357342	19.60	.367345	20.07	15	.425220	18.12	.436938	18.62
16	.358518	19.58	.368549	20.03	16	.426307	18.10	.438055	18.58
17	.359693	19.55	.369751	20.02	17	.427393	18.07	.439170	18.57
18	.360866	19.53	.370952	19.98	18	.428477	18.05	.440284	18.55
19	.362038	19.50	.372151	19.95	19	.429560	18.02	.441397	18.53
20	.363208	19.48	.373348	19.95	20	.430641	18.02	.442509	18.50
21	8.364377	19.43	8.374545	19.90	21	8.431722	17.97	8.443619	18.47
22	.365543	19.43	.375739	19.88	22	.432800	17.97	.444727	18.47
23	.366709	19.38	.376932	19.85	23	.433878	17.93	.445835	18.43
24	.367872	19.37	.378123	19.83	24	.434954	17.92	.446941	18.42
25	.369034	19.35	.379313	19.82	25	.436029	17.88	.448046	18.38
26	.370195	19.32	.380502	19.78	26	.437102	17.87	.449149	18.38
27	.371354	19.28	.381689	19.75	27	.438174	17.85	.450252	18.35
28	.372511	19.27	.382874	19.73	28	.439245	17.82	.451353	18.32
29	.373667	19.25	.384058	19.70	29	.440314	17.80	.452452	18.32
30	.374822	19.20	.385240	19.68	30	.441382	17.78	.453551	18.28
31	8.375974	19.18	8.386421	19.65	31	8.442449	17.75	8.454648	18.25
32	.377125	19.17	.387600	19.63	32	.443514	17.73	.455743	18.25
33	.378275	19.13	.388778	19.60	33	.444578	17.72	.456838	18.22
34	.379423	19.12	.389954	19.58	34	.445641	17.68	.457931	18.20
35	.380570	19.08	.391129	19.55	35	.446702	17.68	.459023	18.18
36	.381715	19.05	.392302	19.53	36	.447763	17.63	.460114	18.15
37	.382858	19.03	.393474	19.50	37	.448821	17.63	.461203	18.13
38	.384000	19.02	.394644	19.48	38	.449879	17.60	.462291	18.12
39	.385141	18.98	.395813	19.45	39	.450935	17.58	.463378	18.10
40	.386280	18.95	.396980	19.43	40	.451990	17.55	.464464	18.07
41	8.387417	18.93	8.398146	19.42	41	8.453043	17.55	8.465548	18.05
42	.388553	18.92	.399311	19.38	42	.454096	17.52	.466631	18.03
43	.389688	18.88	.400474	19.35	43	.455147	17.48	.467713	18.00
44	.390821	18.85	.401635	19.33	44	.456196	17.48	.468793	18.00
45	.391952	18.83	.402795	19.32	45	.457245	17.45	.469873	17.97
46	.393082	18.82	.403954	19.28	46	.458292	17.43	.470951	17.95
47	.394211	18.78	.405111	19.27	47	.459338	17.40	.472028	17.92
48	.395338	18.75	.406267	19.23	48	.460382	17.40	.473103	17.90
49	.396463	18.73	.407421	19.22	49	.461426	17.37	.474177	17.90
50	.397587	18.72	.408574	19.18	50	.462468	17.35	.475251	17.85
51	8.398710	18.68	8.409725	19.17	51	8.463509	17.32	8.476322	17.85
52	.399831	18.67	.410875	19.13	52	.464548	17.30	.477398	17.83
53	.400951	18.63	.412023	19.13	53	.465586	17.28	.478463	17.80
54	.402069	18.62	.413171	19.08	54	.466623	17.27	.479531	17.7
55	.403186	18.58	.414316	19.08	55	.467659	17.23	.480598	17.
56	.404301	18.57	.415461	19.03	56	.468693	17.23	.481664	17
57	.405415	18.53	.416603	19.03	57	.469727	17.20	.482728	
58	.406527	18.52	.417745	19.00	58	.470759	17.17	.483792	
59	.407638	18.50	.418885	18.98	59	.471789	17.17	.484854	
60	8.408748	18.47	8.420024	18.95	60	8.472819	17.13	8.485915	

	14°					15°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	8.472819	17.13	8.485915	17.67	0	8.532425	15.98	8.547482	16.53
1	.473847	17.12	.486975	17.63	1	.533384	15.97	.548474	16.53
2	.474874	17.10	.488033	17.63	2	.534342	15.95	.549466	16.52
3	.475900	17.08	.489091	17.60	3	.535299	15.93	.550457	16.50
4	.476925	17.05	.490147	17.58	4	.536255	15.92	.551447	16.48
5	.477948	17.03	.491202	17.57	5	.537210	15.88	.552436	16.47
6	.478970	17.02	.492256	17.53	6	.538163	15.88	.553424	16.43
7	.479991	17.00	.493308	17.53	7	.539116	15.87	.554410	16.43
8	.481011	16.97	.494360	17.50	8	.540068	15.83	.555396	16.42
9	.482029	16.95	.495410	17.48	9	.541018	15.83	.556381	16.38
10	.483046	16.93	.496459	17.47	10	.541968	15.80	.557364	16.38
11	8.484062	16.92	8.497507	17.45	11	8.542916	15.78	8.558347	16.37
12	.485077	16.90	.498554	17.43	12	.543863	15.78	.559329	16.33
13	.486091	16.87	.499600	17.40	13	.544810	15.75	.560309	16.33
14	.487103	16.87	.500644	17.38	14	.545755	15.73	.561289	16.30
15	.488115	16.83	.501687	17.38	15	.546699	15.72	.562267	16.30
16	.489125	16.82	.502730	17.35	16	.547642	15.70	.563245	16.28
17	.490134	16.78	.503771	17.32	17	.548584	15.68	.564222	16.25
18	.491141	16.78	.504810	17.32	18	.549525	15.67	.565197	16.25
19	.492148	16.75	.505849	17.30	19	.550465	15.65	.566172	16.22
20	.493153	16.73	.506887	17.27	20	.551404	15.63	.567145	16.22
21	8.494157	16.72	8.507923	17.25	21	8.552342	15.62	8.568118	16.20
22	.495160	16.70	.508958	17.25	22	.553279	15.60	.569090	16.17
23	.496162	16.67	.509993	17.22	23	.554215	15.58	.570060	16.17
24	.497162	16.67	.511026	17.18	24	.555150	15.57	.571030	16.15
25	.498162	16.63	.512057	17.18	25	.556084	15.55	.571999	16.12
26	.499160	16.62	.513088	17.17	26	.557017	15.53	.572966	16.12
27	.500157	16.60	.514118	17.13	27	.557949	15.50	.573933	16.10
28	.501153	16.58	.515146	17.13	28	.558879	15.50	.574899	16.08
29	.502148	16.57	.516174	17.10	29	.559809	15.48	.575864	16.05
30	.503142	16.53	.517200	17.08	30	.560738	15.47	.576827	16.05
31	8.504134	16.52	8.518225	17.07	31	8.561666	15.43	8.577790	16.03
32	.505125	16.52	.519249	17.05	32	.562592	15.43	.578752	16.02
33	.506116	16.48	.520272	17.03	33	.563518	15 42	.579713	16.00
34	.507105	16.45	.521294	17.02	34	.564443	15.40	.580673	15.98
35	.508092	16.45	.522315	16.98	35	.565367	15.37	.581632	15.97
36	.509079	16.43	.523334	16.98	36	.566289	15 37	.582590	15.95
37	.510065	16.40	.524353	16.95	37	.567211	15.35	.583547	15.93
38	.511049	16.40	.525370	16.95	38	.568132	15.33	.584503	15.92
39	.512033	16.37	.526387	16.92	39	.569052	15.30	.585458	15.90
40	.513015	16.35	.527402	16.90	40	.569970	15.30	.586412	15.88
41	8.513996	16.33	8.528416	16.88	41	8.570888	15.28	8.587365	15.88
42	.514976	16.32	.529429	16.87	42	.571805	15.27	.588318	15.85
43	.515955	16.28	.530441	16.85	43	.572721	15.25	.589269	15.83
44	.516932	16.28	.531452	16.83	44	.573636	15.22	.590219	15.83
45	.517909	16.25	.532462	16.82	45	.574549	15.22	.591169	15.80
46	.518884	16.25	.533471	16.78	46	.575462	15.20	.592117	15.80
47	.519859	16.22	.534478	16.78	47	.576374	15.18	.593065	15.78
48	.520832	16.20	.535485	16.75	48	.577285	15.17	.594012	15.75
49	.521804	16.18	.536490	16.75	49	.578195	15.15	.594957	15.75
50	.522775	16.17	.537495	16.72	50	.579104	15.13	.595902	15.73
51	8.523745	16.15	8.538498	16.72	51	8.580012	15.12	8.596846	15.72
52	.524714	16.13	.539501	16.68	52	.580919	15.10	.597789	15.70
53	.525682	16.10	.540502	16.67	53	.581825	15.08	.598731	15.68
54	.526648	16.10	.541502	16.65	54	.582730	15.07	.599672	15.67
55	.527614	16.07	.542501	16.63	55	.583634	15.05	.600612	15.65
56	.528578	16.07	.543499	16.63	56	.584537	15.05	.601551	15.65
57	529542	16.03	.544497	16.60	57	.585440	15.02	.602490	15.62
58	.530504	16.02	.545493	16.58	58	.586341	15.00	.603427	15.60
	.531465	16.00	.546488	16.57	59	.587241	15.00	.604363	15.60
	532425	15.98	8.547482	16.53	60	8.588141	14.97	8.605299	15.5

16°				17°				
Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
8.588141	14.97	8.605299	15.58	0	8.640434	14.08	8.659838	14.72
.589039	14.95	.606234	15.55	1	.641279	14.07	.660721	14.72
.589936	14.95	.607167	15.55	2	.642123	14.05	.661604	14.70
.590833	14.93	.608100	15.53	3	.642966	14.05	.662486	14.68
.591729	14.90	.609032	15.52	4	.643809	14.02	.663367	14.68
.592623	14.90	.609963	15.50	5	.644650	14.02	.664248	14.65
.593517	14.88	.610893	15.50	6	.645491	14.00	.665127	14.65
.594410	14.87	.611823	15.47	7	.646331	13.98	.666006	14.63
.595302	14.83	.612751	15.45	8	.647170	13.97	.666884	14.62
.596192	14.83	.613678	15.45	9	.648008	13.95	.667761	14.60
.597082	14.82	.614605	15.43	10	.648845	13.95	.668637	14.60
8.597971	14.82	8.615531	15.42	11	8.649682	13.93	8.669513	14.58
.598860	14.78	.616456	15.38	12	.650518	13.92	.670388	14.57
.599747	14.77	.617379	15.38	13	.651353	13.90	.671262	14.55
.600633	14.75	.618302	15.38	14	.652187	13.88	.672135	14.55
.601518	14.75	.619225	15.35	15	.653020	13.87	.673008	14.52
.602403	14.72	.620146	15.33	16	.653852	13.87	.673879	14.52
.603286	14.72	.621066	15.33	17	.654684	13.85	.674750	14.50
.604169	14.70	.621986	15.30	18	.655515	13.83	.675620	14.50
.605051	14.67	.622904	15.30	19	.656345	13.82	.676490	14.47
.605931	14.67	.623822	15.28	20	.657174	13.82	.677358	14.47
8.606811	14.65	8.624739	15.27	21	8.658003	13.78	8.678226	14.45
.607690	14.63	.625655	15.25	22	.658830	13.78	.679093	14.45
.608568	14.62	.626570	15.23	23	.659657	13.77	.679960	14.42
.609445	14.60	.627484	15.23	24	.660483	13.75	.680825	14.42
.610321	14.60	.628398	15.20	25	.661308	13.73	.681690	14.40
.611197	14.57	.629310	15.20	26	.662132	13.73	.682554	14.38
.612071	14.57	.630222	15.18	27	.662956	13.72	.683417	14.38
.612945	14.53	.631133	15.17	28	.663779	13.70	.684280	14.35
.613817	14.53	.632043	15.15	29	.664601	13.68	.685141	14.35
.614689	14.52	.632952	15.13	30	.665422	13.67	.686002	14.35
8.615560	14.50	8.633860	15.13	31	8.666242	13.67	8.686863	14.32
.616430	14.48	.634768	15.10	32	.667062	13.65	.687722	14.32
.617299	14.47	.635674	15.10	33	.667881	13.63	.688581	14.30
.618167	14.45	.636580	15.08	34	.668699	13.62	.689439	14.28
.619034	14.45	.637485	15.07	35	.669516	13.60	.690296	14.28
.619901	14.42	.638389	15.05	36	.670332	13.60	.691153	14.25
.620766	14.42	.639292	15.05	37	.671148	13.58	.692008	14.25
.621631	14.40	.640195	15.02	38	.671963	13.57	.692863	14.25
.622495	14.38	.641096	15.02	39	.672777	13.55	.693718	14.22
.623358	14.37	.641997	15.00	40	.673590	13.55	.694571	14.22
8.624220	14.35	8.642897	14.98	41	8.674403	13.53	8.695424	14.20
.625081	14.33	.643796	14.97	42	.675215	13.52	.696276	14.18
.625941	14.33	.644694	14.95	43	.676026	13.50	.697127	14.18
.626801	14.30	.645591	14.95	44	.676836	13.48	.697978	14.17
.627659	14.30	.646488	14.93	45	.677645	13.48	.698828	14.15
.628517	14.28	.647384	14.92	46	.678454	13.47	.699677	14.13
.629374	14.27	.648279	14.90	47	.679262	13.45	.700525	14.13
.630230	14.25	.649173	14.88	48	.680069	13.43	.701373	14.12
.631085	14.23	.650066	14.87	49	.680875	13.43	.702220	14.10
.631939	14.22	.650958	14.87	50	.681681	13.42	.703066	14.10
8.632792	14.22	8.651850	14.85	51	8.682486	13.40	8.703912	14.07
.633645	14.18	.652741	14.83	52	.683290	13.38	.704756	14.07
.634496	14.18	.653631	14.82	53	.684093	13.38	.705600	14.07
.635347	14.17	.654520	14.80	54	.684896	13.35	.706444	14.03
.636197	14.15	.655408	14.80	55	.685697	13.35	.707286	14.03
.637046	14.13	.656296	14.77	56	.686498	13.35	.708128	14.0
.637894	14.13	.657182	14.77	57	.687299	13.32	.708969	14.
.638742	14.10	.658068	14.77	58	.688098	13.32	.709810	14
.639588	14.10	.658954	14.73	59	.688897	13.30	.710650	
8.640434	14.08	8.659838	14.72	60	8.689695	13.28	8.711489	

18°					19°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	8.689695	13.28	8.711489	13.97	0	8.736248	12.58	8.760578	13.30
1	.690492	13.28	.712327	13.95	1	.737003	12.57	.761376	13.30
2	.691289	13.25	.713164	13.95	2	.737757	12.55	.762174	13.28
3	.692084	13.25	.714001	13.95	3	.738510	12.55	.762971	13.27
4	.692879	13.25	.714838	13.92	4	.739263	12.53	.763767	13.27
5	.693674	13.22	.715673	13.92	5	.740015	12.52	.764563	13.25
6	.694467	13.22	.716508	13.90	6	.740766	12.50	.765358	13.23
7	.695260	13.20	.717342	13.88	7	.741516	12.50	.766152	13.23
8	.696052	13.18	.718175	13.88	8	.742266	12.50	.766946	13.22
9	.696843	13.18	.719008	13.87	9	.743016	12.47	.767739	13.20
10	.697634	13.17	.719840	13.85	10	.743764	12.47	.768531	13.20
11	8.698424	13.15	8.720671	13.85	11	8.744512	12.45	8.769323	13.18
12	.699213	13.13	.721502	13.83	12	.745259	12.45	.770114	13.18
13	.700001	13.13	.722332	13.82	13	.746006	12.43	.770905	13.17
14	.700789	13.12	.723161	13.80	14	.746752	12.42	.771695	13.15
15	.701576	13.10	.723989	13.80	15	.747497	12.42	.772484	13.15
16	.702362	13.08	.724817	13.78	16	.748242	12.40	.773273	13.13
17	.703147	13.08	.725644	13.78	17	.748986	12.38	.774061	13.13
18	.703932	13.07	.726471	13.77	18	.749729	12.38	.774849	13.12
19	.704716	13.05	.727297	13.75	19	.750472	12.37	.775636	13.10
20	.705499	13.05	.728122	13.73	20	.751214	12.35	.776422	13.08
21	8.706282	13.02	8.728946	13.73	21	8.751955	12.35	8.777207	13.10
22	.707063	13.02	.729770	13.72	22	.752696	12.33	.777993	13.07
23	.707844	13.02	.730593	13.70	23	.753436	12.32	.778777	13.07
24	.708625	12.98	.731415	13.70	24	.754175	12.32	.779561	13.05
25	.709404	12.98	.732237	13.68	25	.754914	12.30	.780344	13.05
26	.710183	12.97	.733058	13.67	26	.755652	12.28	.781127	13.03
27	.710961	12.97	.733878	13.67	27	.756389	12.28	.781909	13.02
28	.711739	12.95	.734698	13.65	28	.757126	12.27	.782690	13.02
29	.712516	12.93	.735517	13.63	29	.757862	12.27	.783471	13.00
30	.713292	12.92	.736335	13.63	30	.758598	12.25	.784251	13.00
31	8.714067	12.92	8.737153	13.62	31	8.759333	12.23	8.785031	12.98
32	.714842	12.90	.737970	13.60	32	.760067	12.23	.785810	12.97
33	.715616	12.88	.738786	13.60	33	.760801	12.22	.786588	12.97
34	.716389	12.87	.739602	13.58	34	.761534	12.20	.787366	12.97
35	.717161	12.87	.740417	13.57	35	.762266	12.20	.788144	12.93
36	.717933	12.85	.741231	13.57	36	.762998	12.18	.788920	12.93
37	.718704	12.85	.742045	13.55	37	.763729	12.17	.789696	12.93
38	.719475	12.82	.742858	13.53	38	.764459	12.17	.790472	12.92
39	.720244	12.82	.743670	13.53	39	.765189	12.15	.791247	12.90
40	.721013	12.82	.744482	13.52	40	.765918	12.15	.792021	12.90
41	8.721782	12.78	8.745293	13.50	41	8.766647	12.12	8.792795	12.88
42	.722549	12.78	.746103	13.50	42	.767374	12.12	.793568	12.87
43	.723316	12.78	.746913	13.48	43	.768102	12.10	.794340	12.87
44	.724083	12.75	.747722	13.47	44	.768828	12.10	.795112	12.87
45	.724848	12.75	.748530	13.47	45	.769554	12.10	.795884	12.83
46	.725613	12.73	.749338	13.45	46	.770280	12.08	.796654	12.85
47	.726377	12.72	.750145	13.43	47	.771005	12.07	.797425	12.82
48	.727140	12.72	.750951	13.43	48	.771729	12.05	.798194	12.82
49	.727903	12.70	.751757	13.42	49	.772452	12.05	.798963	12.82
50	.728665	12.70	.752562	13.42	50	.773175	12.05	.799732	12.80
51	8.729427	12.67	8.753367	13.40	51	8.773898	12.02	8.800500	12.78
52	.730187	12.67	.754171	13.38	52	.774619	12.02	.801267	12.78
53	.730947	12.67	.754974	13.37	53	.775340	12.02	.802034	12.77
54	.731707	12.63	.755776	13.37	54	.776061	12.00	.802800	12.75
55	.732465	12.63	.756578	13.37	55	.776781	11.98	.803565	12.75
56	.733223	12.63	.757380	13.33	56	.777500	11.97	.804330	12.75
57	.733981	12.60	.758180	13.33	57	.778218	11.97	.805095	12.73
	.734737	12.60	.758980	13.33	58	.778936	11.97	.805859	12.72
	.735493	12.58	.759780	13.30	59	.779654	11.93	.806622	12.7
	.736248	12.58	8.760578	13.30	60	8.780370	11.95	8.807385	12.

	4°					5°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	7.386668	60.17	7.387728	60.32	0	7.580389	48.15	7.582045	48.33
1	.390278	59.93	.391347	60.07	1	.583278	47.98	.584945	48.17
2	.393874	59.67	.394951	59.82	2	.586157	47.82	.587835	48.00
3	.397454	59.43	.398540	59.57	3	.589026	47.67	.590715	47.87
4	.401020	59.18	.402114	59.33	4	.591886	47.52	.593587	47.70
5	.404571	58.93	.405674	59.10	5	.594737	47.35	.596449	47.53
6	.408107	58.70	.409220	58.85	6	.597578	47.20	.599301	47.38
7	.411629	58.47	.412751	58.62	7	.600410	47.05	.602144	47.25
8	.415137	58.23	.416268	58.38	8	.603233	46.90	.604979	47.08
9	.418631	58.00	.419771	58.15	9	.606047	46.73	.607804	46.92
10	.422111	57.77	.423260	57.92	10	.608851	46.60	.610619	46.78
11	7.425577	57.53	7.426735	57.70	11	7.611647	46.43	7.613426	46.63
12	.429029	57.30	.430197	57.45	12	.614433	46.30	.616224	46.48
13	.432467	57.08	.433644	57.25	13	.617211	46.15	.619013	46.35
14	.435892	56.85	.437079	57.00	14	.619980	45.98	.621794	46.18
15	.439303	56.63	.440499	56.80	15	.622739	45.87	.624565	46.05
16	.442701	56.42	.443907	56.57	16	.625491	45.70	.627328	45.90
17	.446086	56.20	.447301	56.35	17	.628233	45.57	.630082	45.75
18	.449458	55.97	.450682	56.13	18	.630967	45.42	.632827	45.62
19	.452816	55.77	.454050	55.92	19	.633692	45.28	.635564	45.48
20	.456162	55.55	.457405	55.72	20	.636409	45.13	.638293	45.33
21	7.459495	55.33	7.460748	55.48	21	7.639117	44.98	7.641013	45.18
22	.462815	55.12	.464077	55.28	22	.641816	44.87	.643724	45.07
23	.466122	54.92	.467394	55.08	23	.644508	44.72	.646428	44.90
24	.469417	54.70	.470699	54.87	24	.647191	44.57	.649122	44.78
25	.472699	54.50	.473991	54.65	25	.649865	44.45	.651809	44.65
26	.475969	54.28	.477270	54.47	26	.652532	44.30	.654488	44.50
27	.479226	54.10	.480538	54.25	27	.655190	44.17	.657158	44.37
28	.482472	53.88	.483793	54.05	28	.657840	44.05	.659820	44.23
29	.485705	53.70	.487036	53.85	29	.660483	43.90	.662474	44.12
30	.488927	53.48	.490267	53.67	30	.663117	43.77	.665121	43.97
31	7.492136	53.28	7.493487	53.45	31	7.665743	43.63	7.667759	43.83
32	.495333	53.10	.496694	53.27	32	.668361	43.50	.670389	43.72
33	.498519	52.90	.499890	53.07	33	.670971	43.38	.673012	43.57
34	.501693	52.72	.503074	52.88	34	.673574	43.23	.675626	43.45
35	.504856	52.52	.506247	52.68	35	.676168	43.12	.678233	43.33
36	.508007	52.33	.509408	52.50	36	.678755	42.98	.680833	43.18
37	.511147	52.13	.512558	52.32	37	.681334	42.87	.683424	43.07
38	.514275	51.95	.515697	52.12	38	.683906	42.73	.686008	42.95
39	.517392	51.77	.518824	51.93	39	.686470	42.60	.688585	42.82
40	.520498	51.58	.521940	51.77	40	.689026	42.48	.691154	42.68
41	7 523593	51.40	7.525046	51.57	41	7.691575	42.35	7.693715	42.57
42	.526677	51.22	.528140	51.38	42	.694116	42.23	.696269	42.43
43	.529750	51.03	.531223	51.22	43	.696650	42.12	.698815	42.33
44	.532812	50.85	.534296	51.02	44	.699177	41.98	.701355	42.20
45	.535863	50.68	.537357	50.85	45	.701696	41.87	.703887	42.07
46	.538904	50.50	.540408	50.68	46	.704208	41.73	.706411	41.97
47	.541934	50.32	.543449	50.50	47	.706712	41.63	.708929	41.83
48	.544953	50.15	.546479	50.33	48	.709210	41.50	.711439	41.72
49	.547962	49.98	.549499	50.15	49	.711700	41.38	.713942	41.60
50	.550961	49.80	.552508	49.98	50	.714183	41.27	.716438	41.48
51	7.553949	49.63	7.555507	49.80	51	7.716659	41.15	7.718927	41.37
52	.556927	49.47	.558495	49.65	52	.719128	41.03	.721409	41.25
53	.559895	49.28	.561474	49.47	53	.721590	40.92	.723884	41.13
54	.562852	49.13	.564442	49.32	54	.724045	40.80	.726352	41.02
55	.565800	48.95	.567401	49.13	55	.726493	40.68	.728813	40.90
56	.568737	48.80	.570349	48.98	56	.728934	40.57	.731267	40.78
57	.571665	48.63	.573288	48.82	57	.731368	40.47	.733714	40.68
58	.574583	48.47	.576217	48.65	58	.733796	40.33	.736155	40.57
59	.577491	48.30	.579136	48.48	59	.736216	40.23	.738589	40.45
60	7.580389	48.15	7.582045	48.33	60	7.738630	40.13	7.741016	40.35

6°					7°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	7.738630	40.13	7.741016	40.33	0	7.872381	34.38	7.875630	34.63
1	.741038	40.00	.743436	40.23	1	.874444	34.30	.877708	34.57
2	.743438	39.90	.745850	40.13	2	.876502	34.22	.879782	34.48
3	.745832	39.78	.748258	40.00	3	.878555	34.13	.881851	34.40
4	.748219	39.68	.750658	39.90	4	.880603	34.07	.883915	34.32
5	.750600	39.57	.753052	39.80	5	.882647	33.98	.885974	34.25
6	.752974	39.47	.755440	39.68	6	.884686	33.90	.888029	34.15
7	.755342	39.35	.757821	39.58	7	.886720	33.82	.890078	34.08
8	.757703	39.25	.760196	39.48	8	.888749	33.73	.892123	34.02
9	.760058	39.13	.762565	39.37	9	.890773	33.67	.894164	33.92
10	.762406	39.05	.764927	39.25	10	.892793	33.58	.896199	33.85
11	7.764749	38.92	7.767282	39.17	11	7.894808	33.50	7.898230	33.77
12	.767084	38.83	.769632	39.05	12	.896818	33.43	.900256	33.70
13	.769414	38.72	.771975	38.95	13	.898824	33.35	.902278	33.62
14	.771737	38.62	.774312	38.85	14	.900825	33.27	.904295	33.53
15	.774054	38.52	.776643	38.75	15	.902821	33.20	.906307	33.47
16	.776365	38.42	.778968	38.63	16	.904813	33.12	.908315	33.40
17	.778670	38.30	.781286	38.55	17	.906800	33.05	.910319	33.30
18	.780968	38.22	.783599	38.43	18	.908783	32.97	.912317	33.25
19	.783261	38.10	.785905	38.35	19	.910761	32.90	.914312	33.17
20	.785547	38.02	.788206	38.23	20	.912735	32.82	.916302	33.08
21	7.787828	37.90	7.790500	38.15	21	7.914704	32.73	7.918287	33.02
22	.790102	37.82	.792789	38.03	22	.916668	32.68	.920268	32.95
23	.792371	37.70	.795071	37.95	23	.918629	32.58	.922245	32.87
24	.794633	37.62	.797348	37.85	24	.920584	32.53	.924217	32.78
25	.796890	37.52	.799619	37.75	25	.922536	32.45	.926184	32.73
26	.799141	37.40	.801884	37.65	26	.924483	32.37	.928148	32.65
27	.801385	37.33	.804143	37.57	27	.926425	32.32	.930107	32.58
28	.803625	37.22	.806397	37.45	28	.928364	32.22	.932062	32.50
29	.805858	37.13	.808644	37.37	29	.930297	32.17	.934012	32.43
30	.808086	37.03	.810886	37.28	30	.932227	32.08	.935958	32.37
31	7.810308	36.93	7.813123	37.17	31	7.934152	32.02	7.937900	32.30
32	.812524	36.83	.815353	37.08	32	.936073	31.95	.939838	32.23
33	.814734	36.75	.817578	37.00	33	.937990	31.88	.941772	32.15
34	.816939	36.67	.819798	36.90	34	.939903	31.80	.943701	32.08
35	.819139	36.55	.822012	36.80	35	.941811	31.73	.945626	32.02
36	.821332	36.48	.824220	36.72	36	.943715	31.67	.947547	31.95
37	.823521	36.37	.826423	36.62	37	.945615	31.60	.949464	31.87
38	.825708	36.28	.828620	36.53	38	.947511	31.52	.951376	31.82
39	.827880	36.20	.830812	36.45	39	.949402	31.47	.953285	31.73
40	.830052	36.10	.832999	36.35	40	.951290	31.38	.955189	31.68
41	7.832218	36.02	7.835180	36.27	41	7.953173	31.32	7.957090	31.60
42	.834379	35.93	.837356	36.17	42	.955052	31.27	.958986	31.53
43	.836535	35.83	.839526	36.08	43	.956928	31.18	.960878	31.48
44	.838685	35.75	.841691	36.00	44	.958799	31.12	.962767	31.40
45	.840830	35.65	.843851	35.90	45	.960666	31.05	.964651	31.33
46	.842969	35.58	.846005	35.83	46	.962529	30.98	.966531	31.28
47	.845104	35.48	.848155	35.73	47	.964388	30.92	.968408	31.20
48	.847233	35.40	.850299	35.63	48	.966243	30.85	.970280	31.13
49	.849357	35.30	.852437	35.57	49	.968094	30.78	.972148	31.08
50	.851475	35.23	.854571	35.48	50	.969941	30.73	.974013	31.02
51	7.853589	35.13	7.856700	35.38	51	7.971785	30.65	7.975874	30.93
52	.855697	35.05	.858823	35.32	52	.973624	30.58	.977730	30.88
53	.857800	34.97	.860942	35.22	53	.975459	30.53	.979583	30.82
54	.859898	34.88	.863055	35.13	54	.977291	30.45	.981432	30.75
55	.861991	34.80	.865163	35.05	55	.979118	30.40	.983277	30.70
56	.864079	34.72	.867266	34.98	56	.980942	30.33	.985119	30.62
57	.866162	34.63	.869365	34.88	57	.982762	30.27	.986956	30.57
58	.868240	34.55	.871458	34.80	58	.984578	30.22	.988790	30.50
59	.870313	34.47	.873546	34.73	59	.986391	30.13	.990620	30.43
60	7.872381	34.38	7.875630	34.63	60	7.988193	30.08	7.992446	30.38

	8°					9°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	7.988199	30.08	7.992446	30.38	0	8.090817	26.72	8.095697	27.05
1	.990004	30.02	.994269	30.32	1	.091920	26.68	.097320	27.02
2	.991805	29.95	.996088	30.25	2	.093521	26.63	.098941	26.97
3	.993602	29.88	.997903	30.18	3	.095119	26.58	.100559	26.92
4	.995395	29.83	7.999714	30.13	4	.096714	26.52	.102174	26.87
5	.997185	29.77	8.001522	30.07	5	.098305	26.48	.103786	26.82
6	7.998971	29.72	.003326	30.00	6	.099894	26.43	.105395	26.77
7	8.000754	29.63	.005126	29.95	7	.101480	26.40	.107001	26.73
8	.002532	29.60	.006923	29.88	8	.103064	26.33	.108605	26.67
9	.004308	29.52	.008716	29.83	9	.104644	26.28	.110205	26.63
10	.006079	29.47	.010506	29.77	10	.106221	26.25	.111803	26.58
11	8.007847	29.40	8.012292	29.70	11	8.107796	26.18	8.113398	26.53
12	.009611	29.35	.014074	29.65	12	.109367	26.15	.114990	26.48
13	.011372	29.28	.015853	29.58	13	.110936	26.10	.116579	26.45
14	.013129	29.22	.017628	29.53	14	.112502	26.05	.118166	26.38
15	.014882	29.17	.019400	29.47	15	.114065	26.00	.119749	26.35
16	.016632	29.10	.021168	29.42	16	.115625	25.95	.121330	26.30
17	.018378	29.05	.022933	29.35	17	.117182	25.92	.122908	26.25
18	.020121	29.00	.024694	29.30	18	.118737	25.87	.124483	26.22
19	.021861	28.93	.026452	29.23	19	.120289	25.82	.126056	26.17
20	.023597	28.87	.028206	29.18	20	.121838	25.77	.127626	26.12
21	8.025329	28.82	8.029957	29.13	21	8.123384	25.72	8.129193	26.07
22	.027058	28.75	.031705	29.07	22	.124927	25.68	.130757	26.02
23	.028783	28.70	.033449	29.00	23	.126468	25.63	.132318	25.98
24	.030505	28.65	.035189	28.97	24	.128006	25.58	.133877	25.93
25	.032224	28.58	.036927	28.90	25	.129541	25.55	.135433	25.90
26	.033939	28.53	.038661	28.83	26	.131074	25.50	.136987	25.85
27	.035651	28.47	.040391	28.78	27	.132604	25.45	.138538	25.80
28	.037359	28.42	.042118	28.73	28	.134131	25.40	.140086	25.75
29	.039064	28.37	.043842	28.68	29	.135655	25.37	.141631	25.72
30	.040766	28.30	.045563	28.62	30	.137177	25.32	.143174	25.67
31	8.042464	28.25	8.047280	28.57	31	8.138696	25.27	8.144714	25.63
32	.044159	28.20	.048994	28.50	32	.140212	25.23	.146252	25.58
33	.045851	28.13	.050704	28.47	33	.141726	25.18	.147787	25.53
34	.047539	28.08	.052412	28.40	34	.143237	25.13	.149319	25.50
35	.049224	28.03	.054116	28.35	35	.144745	25.10	.150849	25.45
36	.050906	27.98	.055817	28.28	36	.146251	25.05	.152376	25.40
37	.052585	27.92	.057514	28.25	37	.147754	25.02	.153900	25.37
38	.054260	27.87	.059209	28.18	38	.149255	24.95	.155422	25.33
39	.055932	27.82	.060900	28.13	39	.150752	24.93	.156942	25.27
40	.057601	27.75	.062588	28.08	40	.152248	24.88	.158458	25.25
41	8.059266	27.72	8.064273	28.03	41	8.153741	24.83	8.159973	25.18
42	.060929	27.65	.065955	27.97	42	.155231	24.78	.161484	25.17
43	.062588	27.60	.067633	27.93	43	.156718	24.75	.162994	25.10
44	.064244	27.55	.069309	27.87	44	.158203	24.72	.164500	25.07
45	.065897	27.48	.070981	27.82	45	.159686	24.67	.166004	25.03
46	.067546	27.45	.072650	27.77	46	.161166	24.62	.167506	24.98
47	.069193	27.38	.074316	27.72	47	.162643	24.58	.169005	24.95
48	.070836	27.33	.075979	27.67	48	.164118	24.53	.170502	24.90
49	.072476	27.30	.077639	27.60	49	.165590	24.50	.171996	24.87
50	.074114	27.23	.079295	27.57	50	.167060	24.45	.173488	24.82
51	8.075748	27.18	8.080949	27.52	51	8.168527	24.42	8.174977	24.78
52	.077379	27.13	.082600	27.45	52	.169992	24.37	.176464	24.73
53	.079007	27.07	.084247	27.42	53	.171454	24.33	.177948	24.70
54	.080631	27.03	.085892	27.37	54	.172914	24.30	.179430	24.65
55	.082253	26.98	.087534	27.30	55	.174372	24.25	.180909	24.62
56	.083872	26.93	.089172	27.27	56	.175827	24.20	.182386	24.58
57	.085488	26.87	.090808	27.20	57	.177279	24.17	.183861	24.53
58	.087100	26.83	.092440	27.17	58	.178729	24.13	.185338	24.50
59	.088710	26.78	.094070	27.12	59	.180177	24.08	.186808	24.47
60	8.090817	26.72	8.095697	27.05	60	8.181622	24.05	8.188271	24.4

	10°					11°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	8.181622	24.05	8.188271	24.42	0	8.264176	21.85	8.272229	22.27
1	.183065	24.00	.189736	24.37	1	.265487	21.82	.273565	22.22
2	.184505	23.97	.191198	24.35	2	.266796	21.78	.274898	22.20
3	.185943	23.93	.192659	24.30	3	.268103	21.75	.276230	22.17
4	.187379	23.88	.194117	24.25	4	.269408	21.72	.277560	22.13
5	.188812	23.85	.195572	24.22	5	.270711	21.68	.278888	22.08
6	.190243	23.80	.197025	24.18	6	.272012	21.65	.280213	22.07
7	.191671	23.77	.198476	24.15	7	.273311	21.62	.281537	22.03
8	.193097	23.73	.199925	24.10	8	.274608	21.58	.282859	22.00
9	.194521	23.68	.201371	24.07	9	.275903	21.57	.284179	21.98
10	.195942	23.65	.202815	24.03	10	.277197	21.52	.285498	21.93
11	8.197361	23.62	8.204257	23.98	11	8.278488	21.48	8.286814	21.90
12	.198778	23.57	.205696	23.95	12	.279777	21.47	.288128	21.88
13	.200192	23.53	.207133	23.92	13	.281065	21.42	.289441	21.83
14	.201604	23.50	.208568	23.88	14	.282350	21.40	.290751	21.82
15	.203014	23.45	.210001	23.83	15	.283634	21.37	.292060	21.78
16	.204421	23.42	.211431	23.80	16	.284916	21.33	.293367	21.75
17	.205826	23.38	.212859	23.77	17	.286196	21.28	.294672	21.72
18	.207229	23.35	.214285	23.72	18	.287473	21.27	.295975	21.68
19	.208630	23.30	.215708	23.70	19	.288749	21.25	.297276	21.67
20	.210028	23.27	.217130	23.65	20	.290024	21.20	.298576	21.62
21	8.211424	23.23	8.218549	23.62	21	8.291296	21.17	8.299873	21.60
22	.212818	23.18	.219966	23.57	22	.292566	21.15	.301169	21.57
23	.214209	23.17	.221380	23.55	23	.293835	21.10	.302463	21.53
24	.215599	23.12	.222793	23.50	24	.295101	21.08	.303755	21.50
25	.216986	23.08	.224203	23.47	25	.296366	21.05	.305045	21.48
26	.218371	23.03	.225611	23.43	26	.297629	21.02	.306334	21.43
27	.219753	23.00	.227017	23.40	27	.298890	20.98	.307620	21.42
28	.221133	22.98	.228421	23.35	28	.300149	20.95	.308905	21.38
29	.222512	22.93	.229822	23.32	29	.301406	20.93	.310188	21.35
30	.223888	22.88	.231221	23.30	30	.302662	20.90	.311469	21.33
31	8.225261	22.87	8.232619	23.25	31	8.303916	20.85	8.312749	21.28
32	.226633	22.82	.234014	23.22	32	.305167	20.85	.314026	21.27
33	.228002	22.78	.235407	23.17	33	.306418	20.80	.315302	21.23
34	.229369	23.77	.236797	23.15	34	.307666	20.77	.316576	21.22
35	.230735	22.70	.238186	23.10	35	.308912	20.75	.317849	21 17
36	.232097	22.68	.239572	23.08	36	.310157	20.72	.319119	21.15
37	.233458	22.65	.240957	23.03	37	.311400	20.68	.320388	21.12
38	.234817	22.60	.242339	23.00	38	.312641	20.65	.321655	21.08
39	.236173	22.57	.243719	22.97	39	.313880	20.62	.322920	21.05
40	.237527	22.55	.245097	22.93	40	.315117	20.60	.324183	21.03
41	8.238880	22.50	8.246473	22.90	41	8.316353	20.57	8.325445	21.00
42	.240230	22.47	.247847	22.87	42	.317587	20.53	.326705	20.98
43	.241578	22.43	.249219	22.83	43	.318819	20.50	.327964	20.93
44	.242924	22.88	.250589	22.80	44	.320049	20.48	.329220	20.92
45	.244267	22.37	.251957	22.75	45	.321278	20.45	.330475	20.88
46	.245609	22.32	.253322	22.73	46	.322505	20.42	.331728	20.87
47	.246948	22.30	.254686	22.68	47	.323730	20.38	.332980	20.82
48	.248286	22.25	.256047	22.67	48	.324953	20.37	.334229	20.80
49	.249621	22.23	.257407	22.62	49	.326175	20.33	.335477	20.78
50	.250955	22.18	.258764	22.60	50	.327395	20.30	.336724	20.73
51	8.252286	22.15	8.260120	22.55	51	8.328613	20.27	8.337968	20.72
52	.253615	22.12	.261473	22.53	52	.329829	20.25	.339211	20.70
53	.254942	22.10	.262825	22.48	53	.331044	20.22	.340453	20.65
54	.256268	22.05	.264174	22.47	54	.332257	20.18	.341692	20.63
55	.257591	22.02	.265522	22.42	55	.333468	20.17	.342930	20.60
56	.258912	21.98	.266867	22.40	56	.334678	20.13	.344166	20.58
57	.260231	21.95	.268211	22.35	57	.335886	20.10	.345401	20.55
58	.261548	21.92	.269552	22.33	58	.337092	20.07	.346634	20.52
59	.262863	21.88	.270892	22 28	59	.338296	20.05	.347865	20.50
60	8.264176	21.85	8.272229	22.27	60	8.339499	20.02	8.349095	20.47

12°					13°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	8.339499	20.02	8.349095	20.47	0	8.408748	18.47	8.420024	18.95
1	.340700	20.00	.350323	20.43	1	.409856	18.43	.421161	18.93
2	.341900	19.95	.351549	20.42	2	.410962	18.42	.422297	18.90
3	.343097	19.95	.352774	20.38	3	.412067	18.40	.423431	18.88
4	.344294	19.90	.353997	20.35	4	.413171	18.38	.424564	18.87
5	.345488	19.88	.355218	20.33	5	.414274	18.35	.425696	18.83
6	.346681	19.85	.356438	20.30	6	.415375	18.32	.426826	18.82
7	.347872	19.82	.357656	20.28	7	.416474	18.30	.427955	18.80
8	.349061	19.80	.358873	20.25	8	.417572	18.28	.429083	18.77
9	.350249	19.77	.360088	20.22	9	.418669	18.25	.430209	18.75
10	.351435	19.75	.361301	20.20	10	.419764	18.23	.431334	18.73
11	8.352620	19.72	8.362513	20.18	11	8.420858	18.22	8.432458	18.70
12	.353803	19.68	.363724	20.13	12	.421951	18.18	.433580	18.67
13	.354984	19.67	.364932	20.12	13	.423042	18.17	.434700	18.67
14	.356164	19.63	.366139	20.10	14	.424132	18.13	.435820	18.63
15	.357342	19.60	.367345	20.07	15	.425220	18.12	.436938	18.62
16	.358518	19.58	.368549	20.03	16	.426307	18.10	.438055	18.58
17	.359693	19.55	.369751	20.02	17	.427393	18.07	.439170	18.57
18	.360866	19.53	.370952	19.98	18	.428477	18.05	.440284	18.55
19	.362038	19.50	.372151	19.95	19	.429560	18.02	.441397	18.53
20	.363208	19.48	.373348	19.95	20	.430641	18.02	.442509	18.50
21	8.364377	19.43	8.374545	19.90	21	8.431722	17.97	8.443619	18.47
22	.365543	19.43	.375739	19.88	22	.432800	17.97	.444727	18.47
23	.366709	19.38	.376932	19.85	23	.433878	17.93	.445835	18.43
24	.367872	19.37	.378123	19.83	24	.434954	17.92	.446941	18.42
25	.369034	19.35	.379313	19.82	25	.436029	17.88	.448046	18.38
26	.370195	19.32	.380502	19.78	26	.437102	17.87	.449149	18.38
27	.371354	19.28	.381689	19.75	27	.438174	17.85	.450252	18.35
28	.372511	19.27	.382874	19.73	28	.439245	17.82	.451353	18.32
29	.373667	19.25	.384058	19.70	29	.440314	17.80	.452452	18.32
30	.374822	19.20	.385240	19.68	30	.441382	17.78	.453551	18.28
31	8.375974	19.18	8.386421	19.65	31	8.442449	17.75	8.454648	18.25
32	.377125	19.17	.387600	19.63	32	.443514	17.73	.455743	18.25
33	.378275	19.13	.388778	19.60	33	.444578	17.72	.456838	18.22
34	.379423	19.12	.389954	19.58	34	.445641	17.68	.457931	18.20
35	.380570	19.08	.391129	19.55	35	.446702	17.68	.459023	18.18
36	.381715	19.05	.392302	19.53	36	.447763	17.63	.460114	18.15
37	.382858	19.03	.393474	19.50	37	.448821	17.63	.461203	18.13
38	.384000	19.02	.394644	19.48	38	.449879	17.60	.462291	18.12
39	.385141	18.98	.395813	19.45	39	.450935	17.58	.463378	18.10
40	.386280	18.95	.396980	19.43	40	.451990	17.55	.464464	18.07
41	8.387417	18.93	8.398146	19.42	41	8.453043	17.55	8.465548	18.05
42	.388553	18.92	.399311	19.38	42	.454096	17.52	.466631	18.03
43	.389688	18.88	.400474	19.35	43	.455147	17.48	.467713	18.00
44	.390821	18.85	.401635	19.33	44	.456196	17.48	.468793	18.00
45	.391952	18.83	.402795	19.32	45	.457245	17.45	.469873	17.97
46	.393082	18.82	.403954	19.28	46	.458292	17.43	.470951	17.95
47	.394211	18.78	.405111	19.27	47	.459338	17.40	.472028	17.92
48	.395338	18.75	.406267	19.23	48	.460382	17.40	.473103	17.90
49	.396463	18.73	.407421	19.22	49	.461426	17.37	.474177	17.90
50	.397587	18.72	.408574	19.18	50	.462468	17.35	.475251	17.85
51	8.398710	18.68	8.409725	19.17	51	8.463509	17.32	8.476322	17.85
52	.399831	18.67	.410875	19.13	52	.464548	17.30	.477393	17.83
53	.400951	18.63	.412023	19.13	53	.465586	17.28	.478463	17.80
54	.402069	18.62	.413171	19.08	54	.466623	17.27	.479531	17.78
55	.403186	18.58	.414316	19.08	55	.467659	17.23	.480598	17.77
56	.404301	18.57	.415461	19.03	56	.468693	17.23	.481664	17.73
57	.405415	18.53	.416603	19.03	57	.469727	17.20	.482728	17.73
58	.406527	18.52	.417745	19.00	58	.470759	17.17	.483792	17.7
59	.407638	18.50	.418885	18.98	59	.471789	17.17	.484854	17.
60	8.408748	18.47	8.420024	18.95	60	8.472819	17.13	8.485915	17

30°					31°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.127022	7.87	9.189492	9.07	0	9.154828	7.58	9.221762	8.8
1	.127494	7.85	.190036	9.07	1	.155283	7.58	.222293	8.8
2	.127965	7.85	.190580	9.07	2	.155738	7.58	.222825	8.8
3	.128436	7.83	.191124	9.07	3	.156193	7.58	.223355	8.8
4	.128906	7.83	.191668	9.05	4	.156648	7.57	.223886	8.8
5	.129376	7.83	.192211	9.05	5	.157102	7.57	.224417	8.8
6	.129846	7.83	.192754	9.05	6	.157556	7.57	.224947	8.8
7	.130316	7.82	.193297	9.05	7	.158010	7.57	.225477	8.8
8	.130785	7.83	.193840	9.03	8	.158464	7.55	.226007	8.8
9	.131255	7.82	.194382	9.05	9	.158917	7.55	.226537	8.8
10	.131724	7.80	.194925	9.03	10	.159370	7.55	.227066	8.8
11	9.132192	7.80	9.195467	9.03	11	9.159823	7.55	9.227595	8.8
12	.132660	7.82	.196009	9.02	12	.160276	7.53	.228125	8.80
13	.133129	7.78	.196550	9.03	13	.160728	7.53	.228653	8.8
14	.133596	7.80	.197092	9.02	14	.161180	7.53	.229182	8.82
15	.134064	7.78	.197633	9.02	15	.161632	7.52	.229711	8.80
16	.134531	7.78	.198174	9.02	16	.162083	7.53	.230239	8.80
17	.134998	7.78	.198715	9.00	17	.162535	7.52	.230767	8.80
18	.135465	7.77	.199255	9.00	18	.162986	7.52	.231295	8.78
19	.135931	7.77	.199795	9.00	19	.163437	7.50	.231822	8.80
20	.136397	7.77	.200335	9.00	20	.163887	7.52	.232350	8.78
21	9.136863	7.77	9.200875	9.00	21	9.164338	7.50	9.232877	8.78
22	.137329	7.75	.201415	8.98	22	.164788	7.48	.233404	8.78
23	.137794	7.77	.201954	9.00	23	.165237	7.50	.233931	8.78
24	.138260	7.73	.202494	8.97	24	.165687	7.48	.234458	8.77
25	.138724	7.75	.203032	8.98	25	.166136	7.48	.234984	8.77
26	.139189	7.73	.203571	8.98	26	.166585	7.48	.235510	8.77
27	.139653	7.73	.204110	8.97	27	.167034	7.48	.236036	8.77
28	.140117	7.73	.204648	8.97	28	.167483	7.47	.236562	8.77
29	.140581	7.73	.205186	8.97	29	.167931	7.47	.237088	8.75
30	.141045	7.72	.205724	8.97	30	.168379	7.47	.237613	8.77
31	9.141508	7.72	9.206262	8.95	31	9.168827	7.47	9.238139	8.75
32	.141971	7.72	.206799	8.97	32	.169275	7.45	.238664	8.75
33	.142434	7.70	.207337	8.95	33	.169722	7.45	.239189	8.73
34	.142896	7.70	.207874	8.93	34	.170169	7.45	.239713	8.75
35	.143358	7.70	.208410	8.95	35	.170616	7.43	.240238	8.73
36	.143820	7.70	.208947	8.93	36	.171062	7.45	.240762	8.73
37	.144282	7.68	.209483	8.95	37	.171509	7.43	.241286	8.73
38	.144743	7.68	.210020	8.93	38	.171955	7.42	.241810	8.72
39	.145204	7.68	.210556	8.92	39	.172400	7.43	.242333	8.73
40	.145665	7.68	.211091	8.93	40	.172846	7.42	.242857	8.72
41	9.146126	7.67	9.211627	8.92	41	9.173291	7.42	9.243380	8.72
42	.146586	7.67	.212162	8.92	42	.173736	7.42	.243903	8.72
43	.147046	7.67	.212697	8.92	43	.174181	7.42	.244426	8.72
44	.147506	7.67	.213232	8.92	44	.174626	7.40	.244949	8.70
45	.147966	7.65	.213767	8.90	45	.175070	7.40	.245471	8.72
46	.148425	7.65	.214301	8.92	46	.175514	7.40	.245994	8.70
47	.148884	7.65	.214836	8.90	47	.175958	7.40	.246516	8.70
48	.149343	7.63	.215370	8.90	48	.176402	7.38	.247038	8.68
49	.149801	7.63	.215904	8.88	49	.176845	7.38	.247559	8.70
50	.150259	7.63	.216437	8.90	50	.177288	7.38	.248081	8.68
51	9.150717	7.63	9.216971	8.88	51	9.177731	7.38	9.248602	8.68
52	.151175	7.63	.217504	8.88	52	.178174	7.37	.249123	8.68
53	.151633	7.62	.218037	8.88	53	.178616	7.37	.249644	8.68
54	.152090	7.62	.218570	8.87	54	.179058	7.37	.250165	8.68
55	.152547	7.60	.219102	8.88	55	.179500	7.37	.230686	8.67
56	.153003	7.62	.219635	8.87	56	.179942	7.35	.251206	8.6
57	.153460	7.60	.220167	8.87	57	.180383	7.37	.251726	8.67
58	153916	7.60	.220699	8.87	58	.180825	7.33	.252246	8.6
59	.154372	7.60	.221231	8.85	59	.181265	7.35	.252766	8.6
60	9.154828	7.58	9.221762	8.85	60	9.181706	7.35	9.253286	8

32°					33°			
Vers.	D. 1".	Ex. sec.	D. 1".	'	Vers.	D. 1".	Ex. sec.	D. 1".
9.181706	7.35	9.253286	8.65	0	9.207714	7.10	9.284122	8.48
.182147	7.33	.253805	8.65	1	.208140	7.10	.284631	8.47
.182587	7.33	.254324	8.65	2	.208566	7.10	.285139	8.47
.183027	7 32	.254843	8.65	3	.208992	7.10	.285647	8.47
.183466	7.33	.255362	8.65	4	.209418	7.08	.286155	8.47
.183906	7.32	.255881	8.63	5	.209843	7.08	.286663	8.45
.184345	7.32	.256399	8.65	6	.210268	7.08	.287170	8.47
.184784	7.32	.256918	8.63	7	.210693	7.08	.287678	8.45
.185223	7.32	.257436	8.63	8	.211118	7.08	.288185	8.45
.185662	7.30	.257954	8.62	9	.211543	7.07	.288692	8.45
.186100	7 30	.258471	8.63	10	.211967	7.07	.289199	8 43
9.186538	7.30	9.258989	8.62	11	9.212391	7.07	9.289705	8.45
.186976	7.28	.259506	8.62	12	.212815	7.07	.290212	8.43
.187413	7.30	.260023	8.62	13	.213239	7.05	.290718	8.43
.187851	7.28	.260540	8.62	14	.213662	7.05	.291224	8.43
.188288	7.27	.261057	8.62	15	.214085	7.05	.291730	8.43
.188724	7.28	.261574	8.60	16	.214508	7.05	.292236	8.43
.189161	7.27	.262090	8.60	17	.214931	7.05	.292742	8.42
.189597	7.28	.262606	8.60	18	.215354	7.03	.293247	8.43
.190034	7.25	.263122	8.60	19	.215776	7.03	.293753	8.42
.190469	7.27	.263638	8.60	20	.216198	7.03	.294258	8.42
9.190905	7.27	9.264154	8.58	21	9.216620	7.03	9.294763	8.42
.191341	7.25	.264669	8.58	22	.217042	7.02	.295268	8.40
.191776	7.25	.265184	8.60	23	.217463	7.02	.295772	8.42
.192211	7.23	.265700	8.57	24	.217884	7.02	.296277	8.40
.192645	7.25	.266214	8.58	25	.218305	7.02	.296781	8.40
.193080	7.23	.266729	8.58	26	.218726	7.00	.297285	8 40
.193514	7.23	.267244	8.57	27	.219146	7.02	.297789	8.40
.193948	7.23	.267758	8.57	28	.219567	7.00	.298293	8.40
.194382	7.22	.268272	8.57	29	.219987	7.00	.298797	8 38
.194815	7.23	.268786	8.57	30	.220407	6.98	.299300	8.38
9 195249	7.22	9.269300	8.57	31	9.220826	7.00	9.299803	8.40
.195682	7.22	.269814	8.55	32	.221246	6.98	.300307	8.37
.196115	7.20	.270327	8.55	33	.221665	6.98	.300809	8.38
.196547	7.22	.270840	8.57	34	.222084	6.98	.301312	8.38
.196980	7.20	.271354	8.53	35	.222503	6.97	.301815	8.37
.197412	7.20	.271866	8.55	36	.222921	6.98	.302317	8.38
.197844	7.18	.272379	8.55	37	.223340	6.97	.302820	8.37
.198275	7.20	.272892	8.53	38	.223758	6.97	.303322	8.37
.198707	7.18	.273404	8.53	39	.224176	6.95	.303824	8.35
.199138	7.18	.273916	8.53	40	.224593	6.97	.304325	8.37
9.199569	7.18	9.274428	8.53	41	9.225011	6.95	9.304827	8.35
.200000	7.17	.274940	8.53	42	.225428	6.95	.305328	8.37
.200430	7.18	.275452	8.52	43	.225845	6.95	.305830	8.35
.200861	7.17	.275963	8.52	44	.226262	6.93	.306331	8.35
.201291	7.15	.276474	8.53	45	.226678	6.95	.306832	8.35
.201720	7.17	.276986	8.50	46	.227095	6.93	.307333	8.33
.202150	7.15	.277496	8.52	47	.227511	6.93	.307833	8.35
.202579	7.15	.278007	8.52	48	.227927	6.92	.308334	8.33
.203008	7.15	.278518	8.50	49	.228342	6.93	.308834	8 33
.203437	7.15	.279028	8.50	50	.228758	6.92	.309334	8.33
9.203866	7.13	9.279538	8.50	51	9.229173	6.92	9.309834	8.33
.204294	7.15	.280048	8.50	52	.229588	6.92	.310334	8.33
.204723	7.13	.280558	8.50	53	.230003	6.92	.310834	8.32
.205151	7.12	.281068.	8.48	54	.230418	6.90	.311333	8.32
.205578	7.13	.281577	8.50	55	.230832	6.90	.311832	8.32
.206006	7.13	.282087	8.48	56	.231246	6.90	312331	8.3
.206433	7 12	.282596	8.48	57	.231660	6.90	.312830	8.
206860	7.12	.283105	8.48	58	232074	6.88	313329	8
207287	7.12	283614	8.47	59	.232487	6.90	.313828	
9.207714	7.10	9.284122	8.48	60	9.232901	6.88	9.314326	

18°					19°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	8.689695	13.28	8.711480	13.97	0	8.736248	12.58	8.760578	13.30
1	.690492	13.28	.712327	13.95	1	.737003	12.57	.761376	13.30
2	.691289	13.25	.713164	13.95	2	.737757	12.55	.762174	13.28
3	.692084	13.25	.714001	13.95	3	.738510	12.55	.762971	13.27
4	.692879	13.25	.714838	13.92	4	.739263	12.53	.763767	13.27
5	.693674	13.22	.715673	13.92	5	.740015	12.52	.764563	13.25
6	.694467	13.22	.716508	13.90	6	.740766	12.50	.765358	13.23
7	.695260	13.20	.717342	13.88	7	.741516	12.50	.766152	13.23
8	.696052	13.18	.718175	13.88	8	.742266	12.50	.766946	13.22
9	.696843	13.18	.719008	13.87	9	.743016	12.47	.767739	13.20
10	.697634	13.17	.719840	13.85	10	.743764	12.47	.768531	13.20
11	8.698424	13.15	8.720671	13.85	11	8.744512	12.45	8.769323	13.18
12	.699213	13.13	.721502	13.83	12	.745259	12.45	.770114	13.18
13	.700001	13.13	.722332	13.82	13	.746006	12.43	.770905	13.17
14	.700789	13.12	.723161	13.80	14	.746752	12.42	.771695	13.15
15	.701576	13.10	.723989	13.80	15	.747497	12.42	.772484	13.15
16	.702362	13.08	.724817	13.78	16	.748242	12.40	.773273	13.13
17	.703147	13.08	.725644	13.78	17	.748986	12.38	.774061	13.13
18	.703932	13.07	.726471	13.77	18	.749729	12.38	.774849	13.12
19	.704716	13.05	.727297	13.75	19	.750472	12.37	.775636	13.10
20	.705499	13.05	.728122	13.73	20	.751214	12.35	.776422	13.08
21	8.706282	13.02	8.728946	13.73	21	8.751955	12.35	8.777207	13.10
22	.707063	13.02	.729770	13.72	22	.752696	12.33	.777993	13.07
23	.707844	13.02	.730593	13.70	23	.753436	12.32	.778777	13.07
24	.708625	12.98	.731415	13.70	24	.754175	12.32	.779561	13.05
25	.709404	12.98	.732237	13.68	25	.754914	12.30	.780344	13.05
26	.710183	12.97	.733058	13.67	26	.755652	12.28	.781127	13.03
27	.710961	12.97	.733878	13.67	27	.756389	12.28	.781909	13.03
28	.711739	12.95	.734698	13.65	28	.757126	12.27	.782690	13.02
29	.712516	12.93	.735517	13.63	29	.757862	12.27	.783471	13.00
30	.713292	12.92	.736335	13.63	30	.758598	12.25	.784251	13.00
31	8.714067	12.92	8.737153	13.62	31	8.759333	12.23	8.785031	12.98
32	.714842	12.90	.737970	13.60	32	.760067	12.23	.785810	12.97
33	.715616	12.88	.738786	13.60	33	.760801	12.22	.786588	12.97
34	.716389	12.87	.739602	13.58	34	.761534	12.20	.787366	12.97
35	.717161	12.87	.740417	13.57	35	.762266	12.20	.788144	12.93
36	.717933	12.85	.741231	13.57	36	.762998	12.18	.788920	12.93
37	.718704	12.85	.742045	13.55	37	.763729	12.17	.789696	12.93
38	.719475	12.82	.742858	13.53	38	.764459	12.17	.790472	12.92
39	.720244	12.82	.743670	13.53	39	.765189	12.15	.791247	12.90
40	.721013	12.82	.744482	13.52	40	.765918	12.15	.792021	12.90
41	8.721782	12.78	8.745293	13.50	41	8.766647	12.12	8.792795	12.88
42	.722549	12.78	.746103	13.50	42	.767374	12.12	.793568	12.87
43	.723316	12.78	.746913	13.48	43	.768102	12.10	.794340	12.87
44	.724083	12.75	.747722	13.47	44	.768828	12.10	.795112	12.87
45	.724848	12.75	.748530	13.47	45	.769554	12.10	.795884	12.85
46	.725613	12.73	.749338	13.45	46	.770280	12.08	.796654	12.85
47	.726377	12.72	.750145	13.43	47	.771005	12.07	.797425	12.83
48	.727140	12.72	.750951	13.43	48	.771729	12.05	.798194	12.82
49	.727903	12.70	.751757	13.42	49	.772452	12.05	.798963	12.82
50	.728665	12.70	.752562	13.42	50	.773175	12.05	.799732	12.80
51	8.729427	12.67	8.753367	13.40	51	8.773898	12.02	8.800500	12.79
52	.730187	12.67	.754171	13.38	52	.774619	12.02	.801267	12.78
53	.730947	12.67	.754974	13.37	53	.775340	12.02	.802034	12.77
54	.731707	12.63	.755776	13.37	54	.776061	12.00	.802800	12.75
55	.732465	12.63	.756578	13.37	55	.776781	11.98	.803565	12.75
56	.733223	12.63	.757380	13.33	56	.777500	11.97	.804330	12.75
57	.733981	12.60	.758180	13.33	57	.778218	11.97	.805095	12.73
58	.734737	12.60	.758980	13.33	58	.778936	11.97	.805859	12.72
59	.735493	12.58	.759780	13.30	59	.779654	11.93	.806622	12.72
60	8.736248	12.58	8.760578	13.30	60	8.780370	11.95	8.807385	12.70

20°					21				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	8.780370	11.95	8.807385	12.70	0	8.822296	11.35	8.852144	12.17
1	.781087	11.92	.808147	12.68	1	.822977	11.35	.852874	12.17
2	.781802	11.92	.808908	12.68	2	.823658	11.33	.853604	12.13
3	.782517	11.90	.809669	12.68	3	.824338	11.33	.854332	12.15
4	.783231	11.90	.810430	12.67	4	.825018	11.32	.855061	12.13
5	.783945	11.88	.811190	12.65	5	.825697	11.32	.855789	12.12
6	.784658	11.88	.811949	12.65	6	.826376	11.30	.856516	12.12
7	.785371	11.87	.812708	12.63	7	.827054	11.28	.857243	12.10
8	.786083	11.85	.813466	12.63	8	.827731	11.28	.857969	12.10
9	.786794	11.85	.814224	12.62	9	.828408	11.28	.858695	12.08
10	.787505	11.83	.814981	12.60	10	.829085	11.27	.859420	12.08
11	8.788215	11.82	8.815737	12.60	11	8.829761	11.25	8.860145	12.07
12	.788924	11.82	.816493	12.60	12	.830436	11.25	.860869	12.07
13	.789633	11.82	.817249	12.58	13	.831111	11.23	.861593	12.05
14	.790342	11.78	.818004	12.57	14	.831785	11.23	.862316	12.05
15	.791049	11.78	.818758	12.57	15	.832459	11.22	.863039	12.03
16	.791756	11.78	.819512	12.55	16	.833132	11.20	.863761	12.03
17	.792463	11.77	.820265	12.55	17	.833804	11.20	.864483	12.02
18	.793169	11.75	.821018	12.53	18	.834476	11.20	.865204	12.02
19	.793874	11.75	.821770	12.52	19	.835148	11.18	.865925	12.02
20	.794579	11.73	.822521	12.52	20	.835819	11.17	.866646	11.98
21	8.795283	11.73	8.823272	12.52	21	8.836489	11.17	8.867365	12.00
22	.795987	11.72	.824023	12.50	22	.837159	11.17	.868085	11.98
23	.796690	11.70	.824773	12.48	23	.837829	11.15	.868804	11.97
24	.797392	11.70	.825522	12.48	24	.838498	11.13	.869522	11.97
25	.798094	11.68	.826271	12.47	25	.839166	11.13	.870240	11.95
26	.798795	11.68	.827019	12.47	26	.839834	11.12	.870957	11.95
27	.799496	11.67	.827767	12.45	27	.840501	11.12	.871674	11.93
28	.800196	11.67	.828514	12.45	28	.841168	11.10	.872390	11.93
29	.800896	11.63	.829261	12.43	29	.841834	11.10	.873106	11.93
30	.801594	11.65	.830007	12.42	30	.842500	11.08	.873822	11.92
31	8.802293	11.63	8.830752	12.42	31	8.843165	11.07	8.874537	11.90
32	.802991	11.62	.831497	12.42	32	.843829	11.07	.875251	11.90
33	.803688	11.60	.832242	12.40	33	.844493	11.07	.875965	11.88
34	.804384	11.60	.832986	12.38	34	.845157	11.05	.876678	11.88
35	.805080	11.60	.833729	12.38	35	.845820	11.05	.877391	11.88
36	.805776	11.58	.834472	12.38	36	.846483	11.03	.878104	11.87
37	.806471	11.57	.835215	12.37	37	.847145	11.02	.878816	11.87
38	.807165	11.57	.835957	12.35	38	.847806	11.02	.879528	11.85
39	.807859	11.55	.836698	12.35	39	.848467	11.00	.880239	11.83
40	.808552	11.53	.837439	12.33	40	.849127	11.00	.880949	11.83
41	8.809244	11.53	8.838179	12.33	41	8.849787	11.00	8.881659	11.83
42	.809936	11.53	.838919	12.32	42	.850447	10.98	.882369	11.82
43	.810628	11.52	.839658	12.30	43	.851106	10.97	.883078	11.82
44	.811319	11.50	.840396	12.32	44	.851764	10.97	.883787	11.80
45	.812009	11.50	.841135	12.28	45	.852422	10.95	.884495	11.80
46	.812699	11.48	.841872	12.28	46	.853079	10.95	.885203	11.78
47	.813388	11.48	.842609	12.28	47	.853736	10.93	.885910	11.78
48	.814077	11.47	.843346	12.27	48	.854392	10.93	.886617	11.77
49	.814765	11.45	.844082	12.25	49	.855048	10.92	.887323	11.77
50	.815452	11.45	.844817	12.25	50	.855703	10.92	.888029	11.75
51	8.816139	11.43	8.845552	12.25	51	8.856358	10.90	8.888734	11.75
52	.816825	11.43	.846287	12.23	52	.857012	10.90	.889439	11.75
53	.817511	11.42	.847021	12.22	53	.857666	10.88	.890144	11.73
54	.818196	11.42	.847754	12.22	54	.858319	10.88	.890848	11.72
55	.818881	11.40	.848487	12.22	55	.858972	10.87	.891551	11.72
56	.819565	11.40	.849220	12.20	56	.859624	10.87	.892254	11.72
57	.820249	11.38	.849952	12.18	57	.860276	10.85	.892957	11.70
58	.820932	11.37	.850683	12.18	58	.860927	10.85	.893659	11.70
59	.821614	11.37	.851414	12.17	59	.861578	10.83	.894361	11.68
60	8.822296	11.35	8.852144	12.17	60	8.862228	10.82	8.895062	11.68

	38°					39°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.326314	6.12	9.429782	7.75	0	9.348021	5.93	9.457518	7.65
1	.326681	6.10	.430247	7.77	1	.348377	5.95	.457977	7.65
2	.327047	6.12	.430713	7.75	2	.348734	5.93	.458436	7.65
3	.327414	6.10	.431178	7.75	3	.349090	5.93	.458895	7.63
4	.327780	6.10	.431643	7.75	4	.349446	5.93	.459353	7.65
5	.328146	6.10	.432108	7.75	5	.349802	5.93	.459812	7.63
6	.328512	6.10	.432573	7.75	6	.350158	5.93	.460270	7.65
7	.328878	6.08	.433038	7.75	7	.350514	5.92	.460729	7.63
8	.329243	6.10	.433503	7.73	8	.350869	5.93	.461187	7.63
9	.329609	6.08	.433967	7.75	9	.351225	5.92	.461645	7.63
10	.329974	6.08	.434432	7.73	10	.351580	5.92	.462103	7.63
11	9.330339	6.08	9.434896	7.75	11	9.351935	5.92	9.462561	7.63
12	.330704	6.08	.435361	7.73	12	.352290	5.90	.463019	7.63
13	.331069	6.07	.435825	7.73	13	.352644	5.92	.463477	7.62
14	.331433	6.08	.436289	7.73	14	.352999	5.90	.463934	7.63
15	.331798	6.07	.436753	7.73	15	.353353	5.90	.464392	7 62
16	.332162	6.07	.437217	7.72	16	.353707	5.92	.464849	7 63
17	.332526	6.07	.437680	7.73	17	.354062	5.88	.465307	7.62
18	.332890	6.07	.438144	7.73	18	.354415	5.90	.465764	7.62
19	.333254	6.05	.438608	7.72	19	.354769	5.90	.466221	7.62
20	.333617	6.07	.439071	7.72	20	.355123	5.88	.466678	7.62
21	9.333981	6.05	9.439534	7.72	21	9.355476	5.88	9.467135	7.62
22	.334344	6.05	.439997	7.72	22	.355829	5.88	.467592	7.62
23	.334707	6.05	.440460	7.72	23	.356182	5.88	.468049	7.62
24	.335070	6.03	.440923	7.72	24	.356535	5.88	.468506	7.60
25	.335432	6.05	.441386	7.72	25	.356888	5.88	.468962	7.60
26	.335795	6.03	.441849	7.72	26	.357241	5.87	.469418	7.62
27	.336157	6.03	.442312	7.70	27	.357593	5.87	.469875	7.60
28	.336519	6.03	.442774	7.72	28	.357945	5.87	.470331	7.60
29	.336881	6.03	.443237	7.70	29	.358297	5.87	.470787	7.60
30	.337243	6.03	.443699	7.70	30	.358649	5.87	.471243	7.60
31	9.337605	6.02	9.444161	7.70	31	9.359001	5.87	9.471699	7.60
32	.337966	6.03	.444623	7.70	32	.359353	5.85	.472155	7.60
33	.338328	6.02	.445085	7.70	33	.359704	5.87	.472611	7.60
34	.338689	6.02	.445547	7.70	34	.360056	5.85	.473067	7.58
35	.339050	6.02	.446009	7.68	35	.360407	5.85	.473522	7.60
36	.339411	6.00	.446470	7.70	36	.360758	5.83	.473978	7.58
37	.339771	6.02	.446932	7.68	37	.361108	5.85	.474433	7.58
38	.340132	6.00	.447393	7.70	38	.361459	5.85	.474888	7.58
39	.340492	6.00	.447855	7.68	39	.361810	5.83	.475343	7.58
40	340852	6.00	.448316	7.68	40	.362160	5.83	.475798	7.58
41	9.341212	6.00	9.448777	7.68	41	9.362510	5.83	9.476253	7.58
42	.341572	6.00	.449238	7.68	42	.362860	5.83	.476708	7.58
43	.341932	5.98	.449o99	7.68	43	.363210	5.83	.477163	7.58
44	.342291	6.00	.450160	7.67	44	.363560	5.82	.477618	7.57
45	.342651	5.98	.450620	7 68	45	.363909	5.83	.478072	7 58
46	.343010	5.98	.451081	7.67	46	.364259	5.82	.478527	7.57
47	.343369	5.98	.451541	7.68	47	.364608	5.82	.478981	7.57
48	.343728	5.97	.452002	7.67	48	.364957	5.82	.479435	7.58
49	.344086	5.98	.452462	7.67	49	.365306	5.82	.479890	7.57
50	.344445	5.97	.452922	7.67	50	.365655	5.80	.480344	7.57
51	9.344803	5.97	9.453382	7.67	51	9.366003	5.82	9.480798	7.57
52	.345161	5.97	.453842	7.67	52	366352	5.80	.481252	7.55
53	.345519	5.97	.454302	7.67	53	.366700	5.80	.481705	7 57
54	.345877	5.97	.454762	7.65	54	.367048	5.80	.482159	7.57
55	346235	5.95	.455221	7.67	55	.367396	5.80	.482613	7.55
56	346592	5.97	.455681	7.65	56	.367744	5.78	483066	7.57
57	346950	5.95	.456140	7.67	57	368091	5.80	483520	7.55
	.347307	5.95	.456600	7.65	58	368439	5.78	483973	7.55
	.347664	5.95	.457059	7.65	59	368786	5.78	484426	7.5
	9.348021	5.93	9.457518	7.65	60	9.369133	5.78	9 484879	7.5

24°					25°			
Vers.	D. 1".	Ex. sec.	D. 1".	′	Vers.	D. 1".	Ex. sec.	D. 1".
8.936788	9.90	8.976058	10.83	0	8.971703	9.50	9.014428	10.47
.937382	9.90	.976708	10.83	1	.972273	9.48	.015056	10.48
.937976	9.88	.977358	10.83	2	.972842	9.48	.015685	10.45
.938569	9.88	.978008	10.82	3	.973411	9.48	.016312	10.47
.939162	9.87	.978657	10.82	4	.973980	9.47	.016940	10.45
.939754	9.87	.979306	10.80	5	.974548	9.47	.017567	10.45
.940346	9.87	.979954	10.80	6	.975116	9.45	.018194	10.45
.940938	9.85	.980602	10.80	7	.975683	9.45	.018821	10.43
.941529	9.85	.981250	10.80	8	.976250	9.43	.019447	10.43
.942120	9.83	.981898	10.78	9	.976816	9.43	.020073	10.42
.942710	9.83	.982545	10.77	10	.977382	9.43	.020698	10.42
8.943300	9.82	8.983191	10.77	11	8.977948	9.43	9.021323	10.42
.943889	9.83	.983837	10.77	12	.978514	9.42	.021948	10.40
.944479	9.80	.984483	10.77	13	.979079	9.40	.022572	10.42
.945067	9.80	.985129	10.75	14	.979643	9.40	.023197	10.38
.945655	9.80	.985774	10.75	15	.980207	9.40	.023820	10.40
.946243	9.80	.986419	10.73	16	.980771	9.40	.024444	10.38
.946831	9.78	.987063	10.73	17	.981335	9.38	.025067	10.38
.947418	9.77	.987707	10.73	18	.981898	9.37	.025690	10.37
.948004	9.77	.988351	10.72	19	.982460	9.38	.026312	10.37
.948590	9.77	.988994	10.72	20	.983023	9.37	.026934	10.37
8.949176	9.75	8.989637	10.70	21	8.983585	9.35	9.027556	10.35
.949761	9.75	.990279	10.72	22	.984146	9.35	.028177	10.35
.950346	9.75	.990922	10.68	23	.984707	9.35	.028798	10.35
.950931	9.73	.991563	10.70	24	.985268	9.33	.029419	10.33
.951515	9.73	.992205	10.68	25	.985828	9.33	.030039	10.33
.952099	9.72	.992846	10.68	26	.386388	9.33	.030659	10.33
.952682	9.72	.993487	10.67	27	.986948	9.32	.031279	10.33
.953265	9.70	.994127	10.67	28	.987507	9.32	.031899	10.32
.953847	9.70	.994767	10.65	29	.988066	9.32	.032518	10.30
.954429	9.70	.995406	10.67	30	.988625	9.30	.033136	10.32
8.955011	9.68	8.996046	10.65	31	8.989183	9.28	9.033755	10.30
.955592	9.68	.996685	10.63	32	.989740	9.30	.034373	10.30
.956173	9.67	.997323	10.63	33	.990298	9.28	.034991	10.28
.956753	9.68	.997961	10.63	34	.990855	9.27	.035608	10.28
.957334	9.65	.998599	10.62	35	.991411	9.28	.036225	10.28
.957913	9.65	.999236	10.62	36	.991968	9.25	.036842	10.27
.958492	9.65	8.999873	10.62	37	.992523	9.27	.037458	10.27
.959071	9.65	9.000510	10.60	38	.993079	9.25	.038074	10.27
.959650	9.63	.001146	10.62	39	.993634	9.25	.038690	10.25
.960228	9.62	.001783	10.58	40	.994189	9.23	.039305	10.25
8.960805	9.62	9.002418	10.58	41	8.994743	9.23	9.039920	10.25
.961382	9.62	.003053	10.58	42	.995297	9.23	.040535	10.25
.961959	9.60	.003688	10.58	43	.995851	9.22	.041150	10.23
.962535	9.60	.004323	10.57	44	.996404	9.22	.041764	10.23
.963111	9.60	.004957	10.57	45	.996957	9.20	.042378	10.23
.963687	9.58	.005591	10.55	46	.997509	9.22	.042991	10.22
.964262	9.58	.006224	10.57	47	.998062	9.18	.043604	10.22
.964837	9.57	.006858	10.53	48	.998613	9.20	.044217	10.22
.965411	9.57	.007490	10.55	49	.999165	9.18	.044830	10.20
.965985	9.57	.008123	10.53	50	8.999716	9.17	.045442	10.20
8.966559	9.55	9.008755	10.53	51	9.000266	9.18	9.046054	10.15
.967132	9.55	.009387	10.52	52	.000817	9.17	.046665	10.18
.967705	9.53	.010018	10.52	53	.001367	9.15	.047276	10.18
.968277	9.53	.010649	10.52	54	.001916	9.17	.047887	10.18
.968849	9.53	.011280	10.50	55	.002466	9.13	.048498	10.17
.969421	9.52	.011910	10.50	56	.003014	9.15	.049108	10.17
.969992	9.52	.012540	10.50	57	.003563	9.13	.049718	10.17
.970563	9.50	.013170	10.48	58	.004111	9.13	.050328	10.15
.971133	9.50	.013799	10.48	59	.004659	9.12	.050937	10.15
8.971703	9.50	9.014428	10.47	60	9.005206	9.12	9.051546	10.15

	26°					27°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.005206	9.12	9.051546	10.15	0	9.037401	8.77	9.087520	9.83
1	.005753	9.12	.052155	10.13	1	.037927	8.75	.088110	9.83
2	.006300	9.10	.052763	10.13	2	.038452	8.77	.088700	9.83
3	.006846	9.10	.053371	10.13	3	.038978	8.75	.089290	9.83
4	.007392	9.10	.053979	10.12	4	.039503	8.73	.089880	9.82
5	.007938	9.08	.054586	10.12	5	.040027	8.75	.090469	9.82
6	.008483	9.08	.055193	10.12	6	.040552	8.73	.091058	9.82
7	.009028	9.07	.055800	10.10	7	.041076	8.72	.091647	9.80
8	.009572	9.07	.056406	10.10	8	.041599	8.73	.092235	9.80
9	.010116	9.07	.057012	10.10	9	.042123	8.72	.092823	9.80
10	.010660	9.05	.057618	10.10	10	.042646	8.70	.093411	9.78
11	9.011203	9.05	9.058224	10.08	11	9.043168	8.72	9.093998	9.80
12	.011746	9.05	.058829	10.08	12	.043691	8.70	.094586	9.78
13	.012289	9.03	.059434	10.07	13	.044213	8.70	.095173	9.77
14	.012831	9.03	.060038	10.08	14	.044735	8.68	.095759	9.78
15	.013373	9.03	.060643	10.07	15	.045256	8.68	.096346	9.77
16	.013915	9.02	.061247	10.05	16	.045777	8.68	.096932	9.77
17	.014456	9.02	.061850	10.07	17	.046298	8.67	.097518	9.75
18	.014997	9.02	.062454	10.05	18	.046818	8.67	.098103	9.77
19	.015538	9.00	.063057	10.03	19	.047338	8.67	.098689	9.75
20	.016078	9.00	.063659	10.05	20	.047858	8.65	.099274	9.73
21	9.016618	8.98	9.064262	10.03	21	9.048377	8.65	9.099858	9.75
22	.017157	9.00	.064864	10.03	22	.048896	8.65	.100443	9.73
23	.017697	8.97	.065466	10.02	23	.049415	8.63	.101027	9.73
24	.018235	8.98	.066067	10.02	24	.049933	8.63	.101611	9.72
25	.018774	8.97	.066668	10.02	25	.050451	8.63	.102194	9.73
26	.019312	8.97	.067269	10.02	26	.050969	8.63	.102778	9.72
27	.019850	8.95	.067870	10.00	27	.051487	8.62	.103361	9.70
28	.020387	8.95	.068470	10.00	28	.052004	8.60	.103943	9.72
29	.020924	8.95	.069070	10.00	29	.052520	8.62	.104526	9.70
30	.021461	8.93	.069670	9.98	30	.053037	8.60	.105108	9.70
31	9.021997	8.93	9.070269	9.98	31	9.053553	8.60	9.105690	9.68
32	.022533	8.93	.070868	9.98	32	.054069	8.58	.106271	9.70
33	.023069	8.92	.071467	9.97	33	.054584	8.58	.106853	9.68
34	.023604	8.92	.072065	9.97	34	.055099	8.58	.107434	9.68
35	.024139	8.90	.072663	9.97	35	.055614	8.58	.108015	9.67
36	.024673	8.92	.073261	9.97	36	.056129	8.57	.108595	9.67
37	.025208	8.90	.073859	9.95	37	.056643	8.57	.109175	9.67
38	.025742	8.88	.074456	9.95	38	.057157	8.55	.109755	9.67
39	.026275	8.88	.075053	9.93	39	.057670	8.55	.110335	9.65
40	.026808	8.88	.075649	9.95	40	.058183	8.55	.110914	9.67
41	9.027341	8.88	9.076246	9.93	41	9.058696	8.55	9.111494	9.63
42	.027874	8.87	.076842	9.92	42	.059209	8.53	.112072	9.65
43	.028406	8.87	.077437	9.93	43	.059721	8.53	.112651	9.63
44	.028938	8.85	.078033	9.92	44	.060233	8.53	.113229	9.63
45	.029469	8.85	.078628	9.92	45	.060745	8.52	.113807	9.63
46	.030000	8.85	.079223	9.90	46	.061256	8.52	.114385	9.63
47	.030531	8.85	.079817	9.92	47	.061767	8.50	.114963	9.62
48	.031062	8.83	.080412	9.90	48	.062277	8.52	.115540	9.62
49	.031592	8.83	.081006	9.88	49	.062788	8.50	.116117	9.60
50	.032122	8.82	.081599	9.90	50	.063298	8.48	.116693	9.62
51	9.032651	8.82	9.082193	9.88	51	9.063807	8.50	9.117270	9.60
52	.033180	8.82	.082786	9.87	52	.064317	8.48	.117846	9.60
53	.033709	8.80	.083378	9.88	53	.064826	8.48	.118422	9.58
54	.034237	8.80	.083971	9.87	54	.065335	8.47	.118997	9.60
55	.034765	8.80	.084563	9.87	55	.065843	8.47	.119573	9.58
56	.035293	8.78	.085155	9.87	56	.066351	8.47	.120148	9.58
57	.035820	8.78	.085747	9.85	57	.066859	8.45	.120723	9.57
58	.036347	8.78	.086338	9.85	58	.067366	8.47	.121297	9.57
59	.036874	8.78	.086929	9.85	59	.067874	8.43	.121871	9.57
60	9.037401	8.77	9.087520	9.83	60	9.068380	8.45	9.122445	9.57

28°					29°			
Vers.	D. 1".	Ex. sec.	D. 1".	′	Vers.	D. 1".	Ex. sec.	D. 1".
9.068380	8.45	9.122445	9.57	0	9.098229	8.15	9.156410	9.30
.068887	8.43	.123019	9.57	1	.098718	8.13	.156908	9.32
.069393	8.43	.123593	9.55	2	.099206	8.12	.157527	9.28
.069899	8.43	.124166	9.55	3	.099693	8.13	.158084	9.30
.070405	8.42	.124739	9.53	4	.100181	8.12	.158642	9.30
.070910	8.42	.125311	9.55	5	.100668	8.12	.159200	9.28
.071415	8.40	.125884	9.53	6	.101155	8.12	.159757	9.28
.071919	8.42	.126456	9.53	7	.101642	8.10	.160314	9.27
.072424	8.40	.127028	9.52	8	.102128	8.10	.160870	9.28
.072928	8.40	.127599	9.53	9	.102614	8.10	.161427	9.27
.073432	8.38	.128171	9.52	10	.103100	8.08	.161983	9.27
9.073935	8.38	9.128742	9.52	11	9.103585	8.08	9.162539	9.27
.074438	8.38	.129313	9.50	12	.104070	8.08	.163095	9.25
.074941	8.37	.129883	9.50	13	.104555	8.08	.163650	9.25
.075443	8.38	.130453	9.50	14	.105040	8.07	.164205	9.25
.075946	8.35	.131023	9.50	15	.105524	8.07	.164760	9.25
.076447	8.37	.131593	9.50	16	.106008	8.05	.165315	9.25
.076949	8.35	.132163	9.48	17	.106491	8.07	.165870	9.23
.077450	8.35	.132732	9.48	18	.106975	8.05	.166424	9.23
.077951	8.35	.133301	9.48	19	.107458	8.05	.166978	9.23
.078452	8.33	.133870	9.47	20	.107941	8.03	.167532	9.22
9.078952	8.33	9.134438	9.47	21	9.108423	8.05	9.168085	9.23
.079452	8.33	.135006	9.47	22	.108906	8.03	.168639	9.22
.079952	8.32	.135574	9.47	23	.109388	8.02	.169192	9.22
.080451	8.32	.136142	9.45	24	.109869	8.03	.169745	9.20
.080950	8.32	.136709	9.47	25	.110351	8.02	.170297	9.22
.081449	8.32	.137277	9.45	26	.110832	8.02	.170850	9.20
.081948	8.30	.137844	9.43	27	.111313	8.00	.171402	9.20
.082446	8.30	.138410	9.45	28	.111793	8.00	.171954	9.18
.082944	8.28	.138977	9.43	29	.112273	8.00	.172505	9.20
.083441	8.30	.139543	9.43	30	.112753	8.00	.173057	9.18
9.083939	8.28	9.140109	9.42	31	9.113233	8.00	9.173608	9.18
.084436	8.27	.140674	9.43	32	.113713	7.98	.174159	9.18
.084932	8.28	.141240	9.42	33	.114192	7.98	.174710	9.17
.085429	8.27	.141805	9.42	34	.114671	7.97	.175260	9.17
.085925	8.25	.142370	9.40	35	.115149	7.97	.175810	9.17
.086420	8.27	.142934	9.42	36	.115627	7.97	.176360	9.17
.086916	8.25	.143499	9.40	37	.116105	7.97	.176910	9.17
.087411	8.25	.144063	9.40	38	.116583	7.97	.177460	9.15
.087906	8.23	.144627	9.38	39	.117061	7.95	.178009	9.15
.088400	8.25	.145190	9.40	40	.117538	7.95	.178558	9.15
9.088895	8.23	9.145754	9.38	41	9.118015	7.93	9.179107	9.15
.089389	8.22	.146317	9.38	42	.118491	7.95	.179656	9.13
.089882	8.23	.146880	9.37	43	.118968	7.93	.180204	9.13
.090376	8.22	.147442	9.38	44	.119444	7.92	.180752	9.13
.090869	8.22	.148005	9.37	45	.119919	7.90	.181300	9.13
.091362	8.20	.148567	9.37	46	.120395	7.92	.181848	9.12
.091854	8.20	.149129	9.35	47	.120870	7.92	.182395	9.13
.092346	8.20	.149690	9.35	48	.121345	7.92	.182943	9.12
.092838	8.20	.150251	9.37	49	.121820	7.90	.183490	9.10
.093330	8.18	.150813	9.33	50	.122294	7.90	.184036	9.12
9.093821	8.18	9.151373	9.35	51	9.122768	7.90	9.184583	9.10
.094312	8.18	.151934	9.33	52	.123242	7.88	.185129	9.10
094803	8.17	.152494	9.35	53	.123715	7.90	.185675	9 10
.095293	8.17	.153055	9.32	54	.124189	7.88	.186221	9.10
.095783	8.17	.153614	9.33	55	.124662	7.87	.186767	9.08
.096273	8.17	.154174	9.32	56	.125134	7.88	.187312	9.10
.096763	8.15	.154733	9.33	57	.125607	7.87	.187858	9.08
.097252	8.15	.155293	9.30	58	.126079	7.87	.188403	9.07
.097741	*8.13*	*.155851*	9.32	59	.126551	7.85	.188947	9.08
9.098229	*8.15*	*9.156410*	9.30	60	9.127022	7.87	9.189492	9.0

46°					47°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1
0	9.484786	4.97	9.643015	7.13	0	9.502429	4.85	9.668646	7.1
1	.485084	4.95	.643443	7.15	1	.502720	4.83	.669072	7.1
2	.485381	4.95	.643872	7.13	2	.503010	4.83	.669498	7.1
3	.485678	4.97	.644300	7.13	3	.503300	4.85	.669924	7.1
4	.485976	4.95	.644728	7.13	4	.503591	4.83	.670350	7.1
5	.486273	4.95	.645156	7.15	5	.503881	4.83	.670776	7.0
6	.486570	4.93	.645585	7.13	6	.504171	4.82	.671201	7.1
7	.486866	4.95	.646013	7.13	7	.504460	4.83	.671627	7.1
8	.487163	4.95	.646441	7.13	8	.504750	4.83	.672053	7.1
9	.487460	4.93	.646869	7.13	9	.505040	4.82	.672479	7.1
10	.487756	4.95	.647297	7.13	10	.505329	4.82	.672904	7.1
11	9.488053	4.93	9.647725	7.13	11	9.505618	4.83	9.673330	7.1
12	.488349	4.93	.648153	7.13	12	.505908	4.82	.673756	7.0
13	.488645	4.93	.648581	7.13	13	.506197	4.82	.674181	7.1
14	.488941	4.93	.649009	7.12	14	.506486	4.82	.674607	7.0
15	.489237	4.93	.649436	7.13	15	.506775	4.80	.675032	7.1
16	.489533	4.92	.649864	7.13	16	.507063	4.82	.675458	7.08
17	.489828	4.93	.650292	7.13	17	.507352	4.80	.675883	7.10
18	.490124	4.92	.650720	7.12	18	.507640	4.82	.676309	7.08
19	.490419	4.92	.651147	7.13	19	.507929	4.80	.676734	7.08
20	.490714	4.93	.651575	7.12	20	.508217	4.80	.677159	7.08
21	9.491010	4.92	9.652002	7.13	21	9.508505	4.80	9.677584	7.10
22	.491305	4.92	.652430	7.12	22	.508793	4.80	.678010	7.08
23	.491600	4.90	.652857	7.13	23	.509081	4.80	.678435	7.08
24	.491894	4.92	.653285	7.12	24	.509369	4.80	.678860	7.08
25	.492189	4.92	.653712	7.13	25	.509657	4.80	.679285	7.08
26	.492484	4.90	.654140	7.12	26	.509945	4.78	.679710	7.10
27	.492778	4.90	.654567	7.12	27	.510232	4.80	.680136	7.08
28	.493072	4.92	.654994	7.12	28	.510520	4.78	.680561	7.08
29	.493367	4.90	.655421	7.13	29	.510807	4.78	.680986	7.08
30	.493661	4.90	.655849	7.12	30	.511094	4.78	.681411	7.08
31	9.493955	4.90	9.656276	7.12	31	9.511381	4.78	9.681836	7.07
32	.494249	4.88	.656703	7.12	32	.511668	4.78	.682260	7.08
33	.494542	4.90	.657130	7.12	33	.511955	4.77	.682685	7.08
34	.494836	4.90	.657557	7.12	34	.512241	4.78	.683110	7.08
35	.495130	4.88	.657984	7.12	35	.512528	4.78	.683535	7.08
36	.495423	4.88	.658411	7.12	36	.512815	4.77	.683960	7.08
37	.495716	4.88	.658838	7.12	37	.513101	4.77	.684385	7.07
38	.496009	4.88	.659265	7.10	38	.513387	4.77	.684809	7.08
39	.496302	4.88	.659691	7.12	39	.513673	4.77	.685234	7.08
40	.496595	4.88	.660118	7.12	40	.513959	4.77	.685659	7.07
41	9.496888	4.88	9.660545	7.12	41	9.514245	4.77	9.686083	7.08
42	.497181	4.87	.660972	7.10	42	.514531	4.77	.686508	7.08
43	.497473	4.88	.661398	7.12	43	.514817	4.75	.686933	7.07
44	.497766	4.87	.661825	7.12	44	.515102	4.77	.687357	7.08
45	.498058	4.87	.662252	7.10	45	.515388	4.75	.687782	7.07
46	.498350	4.88	.662678	7.12	46	.515673	4.77	.688206	7.08
47	.498643	4.87	.663105	7.10	47	.515959	4.75	.688631	7.07
48	.498935	4.85	.663531	7.12	48	.516244	4.75	.689055	7.07
49	.499226	4.87	.663958	7.10	49	.516529	4.75	.689479	7.08
50	.499518	4.87	.664384	7.10	50	.516814	4.73	.689904	7.07
51	9.499810	4.85	9.664810	7.12	51	9.517098	4.75	9.690328	7.07
52	.500101	4.87	.665237	7.10	52	.517383	4.75	.690752	7.08
53	.500393	4.85	.665663	7.10	53	.517668	4.73	.691177	7.07
54	.500684	4.85	.666089	7.10	54	.517952	4.73	.691601	7.07
55	.500975	4.85	.666515	7.12	55	.518236	4.75	.692025	7.07
56	.501266	4.85	.666942	7.10	56	.518521	4.73	.692449	7.07
57	.501557	4.85	.667368	7.10	57	.518805	4.73	.692873	7.08
58	.501848	4.85	.667794	7.10	58	.519089	4.73	.693298	7.0
	.502139	4.83	.668220	7.10	59	.519373	4.73	.693722	7.
	.502429	4.85	9.668646	7.10	60	9.519657	4.72	9.694146	

32°					33°			
Vers.	D. 1".	Ex. sec.	D. 1".	'	Vers.	D. 1".	Ex. sec.	D. 1".
9.181706	7.35	9.253286	8.65	0	9.207714	7.10	9.284122	8.48
.182147	7.33	.253805	8.65	1	.208140	7.10	.284631	8.47
.182587	7.33	.254324	8.65	2	.208566	7.10	.285139	8.47
.183027	7 32	.254843	8.65	3	.208992	7.10	.285647	8.47
.183466	7.33	.255362	8.65	4	.209418	7.08	.286155	8.47
.183906	7.32	.255881	8.63	5	.209843	7.08	.286663	8.45
.184345	7.32	.256399	8.65	6	.210268	7.08	.287170	8.47
.184784	7.32	.256918	8.63	7	.210693	7.08	.287678	8.45
.185223	7.32	.257436	8.63	8	.211118	7.08	.288185	8.45
.185662	7.30	.257954	8.62	9	.211543	7.07	.288692	8.45
.186100	7 30	.258471	8.63	10	.211967	7.07	.289199	8 43
9.186538	7.30	9.258989	8.62	11	9.212391	7.07	9.289705	8.45
.186976	7.28	.259506	8.62	12	.212815	7.07	.290212	8.43
.187413	7.30	.260023	8.62	13	.213239	7.05	.290718	8.43
.187851	7.28	.260540	8.62	14	.213662	7.05	.291224	8.43
.188288	7.27	.261057	8.62	15	.214085	7.05	.291730	8.43
.188724	7.28	.261574	8.60	16	.214508	7.05	.292236	8.43
.189161	7.27	.262090	8.60	17	.214931	7.05	.292742	8.42
.189597	7.28	.262606	8.60	18	.215354	7.03	.293247	8.43
.190034	7.25	.263122	8.60	19	.215776	7.03	.293753	8.42
.190469	7.27	.263638	8.60	20	.216198	7.03	.294258	8.42
9.190905	7.27	9.264154	8.58	21	9.216620	7.03	9.294763	8.42
.191341	7.25	.264669	8.58	22	.217042	7.02	.295268	8.40
.191776	7.25	.265184	8.60	23	.217463	7.02	.295772	8.42
.192211	7.23	.265700	8.57	24	.217884	7.02	.296277	8.40
.192645	7.25	.266214	8.58	25	.218305	7.02	.296781	8.40
.193080	7.23	.266729	8.58	26	.218726	7.00	.297285	8 40
.193514	7.23	.267244	8.57	27	.219146	7.02	.297789	8.40
.193948	7.23	.267758	8.57	28	.219567	7.00	.298293	8.40
.194382	7.22	.268272	8.57	29	.219987	7.00	.298797	8 38
.194815	7.23	.268786	8.57	30	.220407	6.98	.299300	8.38
9.195249	7.22	9.269300	8.57	31	9.220826	7.00	9.299803	8.40
.195682	7.22	.269814	8.55	32	.221246	6.98	.300307	8.37
.196115	7.20	.270327	8.55	33	.221665	6.98	.300809	8.38
.196547	7.22	.270840	8.57	34	.222084	6.98	.301312	8.38
.196980	7.20	.271354	8.53	35	.222503	6.97	.301815	8.37
.197412	7.20	.271866	8.55	36	.222921	6.98	.302317	8.38
.197844	7.18	.272379	8.55	37	.223340	6.97	.302820	8.37
.198275	7.20	.272892	8.53	38	.223758	6.97	.303322	8.37
.198707	7.18	.273404	8.53	39	.224176	6.95	.303824	8.35
.199138	7.18	.273916	8.53	40	.224593	6.97	.304325	8.37
9.199569	7.18	9.274428	8.53	41	9.225011	6.95	9.304827	8.35
.200000	7.17	.274940	8.53	42	.225428	6.95	.305328	8.37
.200430	7.18	.275452	8.52	43	.225845	6.95	.305830	8.35
.200861	7.17	.275963	8.52	44	.226262	6.93	.306331	8.35
.201291	7.15	.276474	8.53	45	.226678	6.95	.306832	8.35
.201720	7.17	.276986	8.50	46	.227095	6.93	.307333	8.33
.202150	7.15	.277496	8.52	47	.227511	6.93	.307833	8.35
.202579	7.15	.278007	8.52	48	.227927	6.92	.308334	8.33
.203008	7.15	.278518	8.50	49	.228342	6.93	.308834	8 33
.203437	7.15	.279028	8.50	50	.228758	6.92	.309334	8.33
9.203866	7.13	9.279538	8.50	51	9.229173	6.92	9.309834	8.33
.204294	7.15	.280048	8.50	52	.229588	6.92	.310334	8.33
.204723	7.13	.280558	8.50	53	.230003	6.92	.310834	8.32
.205151	7 12	.281068.	8.48	54	.230418	6.90	.311333	8.32
.205578	7.13	.281577	8.50	55	.230832	6.90	.311832	8.32
.206006	7.13	.282087	8.48	56	.231246	6.90	312331	8.32
.206433	7 12	.282596	8.48	57	.231660	6.90	.312830	8.32
.206860	7.12	.283105	8.48	58	232074	6.88	.313329	8.32
.207287	7.12	283614	8.47	59	.232487	6.90	.313828	8.3
9.207714	7.10	9.284122	8.48	60	9.232901	6.88	9.314326	8.3

	54°					55°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D
0	9.615124	4.12	9.845905	7.03	0	9.629841	4.05	9.871250	
1	.615371	4.13	.846327	7.03	1	.630084	4.03	.871673	
2	.615619	4.13	.846749	7.02	2	.630326	4.05	.872096	
3	.615867	4.13	.847170	7.03	3	.630569	4.03	.872519	
4	.616115	4.12	.847592	7.03	4	.630811	4.05	.872942	
5	.616362	4.13	.848014	7.03	5	.631054	4.03	.873366	
6	.616610	4.12	.848436	7.03	6	.631296	4.03	.873789	
7	.616857	4.12	.848858	7.03	7	.631538	4.03	.874212	
8	.617104	4.12	.849280	7.03	8	.631780	4.03	.874636	
9	.617351	4.12	.849702	7.03	9	.632022	4.03	.875059	
10	.617598	4.12	.850124	7.03	10	.632264	4.02	.875482	
11	9.617845	4.12	9.850546	7.03	11	9.632505	4.03	9.875906	
12	.618092	4.12	.850968	7.03	12	.632747	4.03	.876329	
13	.618339	4.12	.851390	7.03	13	.632989	4.02	.876752	
14	.618586	4.12	.851812	7.03	14	.633230	4.03	.877176	
15	.618833	4.10	.852234	7.03	15	.633472	4.02	.877599	
16	.619079	4.12	.852656	7.03	16	.633713	4.02	.878023	
17	.619326	4.10	.853078	7.03	17	.633954	4.03	.878446	
18	.619572	4.10	.853500	7.05	18	.634196	4.02	.878870	
19	.619818	4.12	.853923	7.03	19	.634437	4.02	.879294	
20	.620065	4.10	.854345	7.03	20	.634678	4.02	.879717	
21	9.620311	4.10	9.854767	7.03	21	9.634919	4.00	9.880141	
22	.620557	4.10	.855189	7.05	22	.635159	4.02	.880565	
23	.620803	4.08	.855612	7.03	23	.635400	4.02	.880988	
24	.621048	4.10	.856034	7.03	24	.635641	4.00	.881412	
25	.621294	4.10	.856456	7.03	25	.635881	4.02	.881836	
26	.621540	4.10	.856878	7.05	26	.636122	4.00	.882260	
27	.621786	4.08	.857301	7.03	27	.636362	4.02	.882683	
28	.622031	4.08	.857723	7 03	28	.636603	4.00	.883107	
29	.622276	4.10	.858145	7.05	29	.636843	4.00	.883531	
30	.622522	4.08	.858568	7.03	30	.637083	4.00	.883955	
31	9.622767	4.08	9.858990	7.05	31	9.637323	4.00	9.884379	
32	.623012	4.08	.859413	7.03	32	.637563	4.00	.884803	
33	.623257	4.08	.859835	7.05	33	.637803	4.00	.885227	
34	.623502	4.08	.860258	7.03	34	.638043	4.00	.885651	
35	.623747	4.08	.860680	7.05	35	.638283	3.98	.886075	
36	.623992	4.08	.861103	7.03	36	.638522	4.00	.886499	
37	.624237	4.07	.861525	7.05	37	.638762	3.98	.886923	
38	.624481	4.08	.861948	7.03	38	.639001	4.00	.887347	
39	.624726	4.07	.862370	7.05	39	.639241	3.98	.887772	
40	.624970	4.08	.862793	7.03	40	.639480	3.98	.888196	
41	9.625215	4 07	9.863215	7.05	41	9.639719	3.98	9.888620	
42	.625459	4.07	.863638	7.05	42	.639958	3.98	.889044	
43	.625703	4.07	.864061	7.03	43	.640197	3.98	.889469	
44	.625947	4.07	.864483	7.05	44	.640436	3.98	.889893	
45	.626191	4.07	.864906	7.05	45	.640675	3.98	.890317	
46	.626435	4.07	.865329	7.05	46	.640914	3.98	.890742	
47	.626679	4.07	.865752	7.03	47	.641153	3.97	.891166	
48	.626923	4.05	.866174	7.05	48	.641391	3.98	.891591	
49	.627166	4.07	.866597	7.05	49	.641630	3.97	.892015	
50	.627410	4.07	.867020	7.05	50	.641868	3.98	.892440	
51	9.627654	4.05	9.867443	7.05	51	9.642107	3.97	9.892864	
52	.627897	4.05	.867866	7.05	52	.642345	3.97	.893289	
53	.628140	4.07	.868289	7.05	53	.642583	3.98	.893714	
54	.628384	4.05	.868712	7.05	54	.642822	3.97	.894138	
55	.628627	4.05	.869135	7.05	55	.643060	3.97	.894563	
56	.628870	4.05	.869558	7.05	56	.643298	3.95	.894988	
57	.629113	4.05	.869981	7.05	57	.643535	3.97	.895412	
58	.629356	4.03	.870404	7.05	58	.643773	3.97	.895837	
59	.629598	4.05	.870827	7.05	59	.644011	3.97	.89626	
	9.629841	4.05	9.871250	7.05	60	9.644249	3.95	9.8966	

32°					33°			
Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
9.181706	7.35	9.253286	8.65	0	9.207714	7.10	9.284122	8.48
.182147	7.33	.253805	8.65	1	.208140	7.10	.284631	8.47
.182587	7.33	.254324	8.65	2	.208566	7.10	.285139	8.47
.183027	7 32	.254843	8.65	3	.208992	7.10	.285647	8.47
.183466	7.33	.255362	8.65	4	.209418	7.08	.286155	8.47
.183906	7.32	.255881	8.63	5	.209843	7.08	.286663	8.45
.184345	7.32	.256399	8.65	6	.210268	7.08	.287170	8.47
.184784	7.32	.256918	8.63	7	.210693	7.08	.287678	8.45
.185223	7.32	.257436	8.63	8	.211118	7.08	.288185	8.45
.185662	7.30	.257954	8.62	9	.211543	7.07	.288692	8.45
.186100	7 30	.258471	8.63	10	.211967	7.07	.289199	8 43
9.186538	7.30	9.258989	8.62	11	9.212391	7.07	9.289705	8.45
.186976	7.28	.259506	8.62	12	.212815	7.07	.290212	8.43
.187413	7.30	.260023	8.62	13	.213239	7.05	.290718	8.43
.187851	7.28	.260540	8.62	14	.213662	7.05	.291224	8.43
.188288	7.27	.261057	8.62	15	.214085	7.05	.291730	8.43
.188724	7.28	.261574	8.60	16	.214508	7.05	.292236	8.43
.189161	7.27	.262090	8.60	17	.214931	7.05	.292742	8.42
.189597	7.28	.262606	8.60	18	.215354	7.03	.293247	8.43
.190034	7.25	.263122	8.60	19	.215776	7.03	.293753	8.42
.190469	7.27	.263638	8.60	20	.216198	7.03	.294258	8.42
9.190905	7.27	9.264154	8.58	21	9.216620	7.03	9.294763	8.42
.191341	7.25	.264669	8.58	22	.217042	7.02	.295268	8.40
.191776	7.25	.265184	8.60	23	.217463	7.02	.295772	8.42
.192211	7.23	.265700	8.57	24	.217884	7.02	.296277	8.40
.192645	7.25	.266214	8.58	25	.218305	7.02	.296781	8.40
.193080	7.23	.266729	8.58	26	.218726	7.00	.297285	8 40
.193514	7.23	.267244	8.57	27	.219146	7.02	.297789	8.40
.193948	7.23	.267758	8.57	28	.219567	7.00	.298293	8.40
.194382	7.22	.268272	8.57	29	.219987	7.00	.298797	8 38
.194815	7.23	.268786	8.57	30	.220407	6.98	.299300	8.38
9 195249	7.22	9.269300	8.57	31	9.220826	7.00	9.299803	8.40
.195682	7.22	.269814	8 55	32	.221246	6.98	.300307	8.37
.196115	7.20	.270327	8.55	33	.221665	6.98	.300809	8.38
.196547	7.22	.270840	8.57	34	.222084	6.98	.301312	8.38
.196980	7.20	.271354	8.53	35	.222503	6.97	.301815	8.37
.197412	7.20	.271866	8.55	36	.222921	6.98	.302317	8.38
.197844	7.18	.272379	8.55	37	.223340	6.97	.302820	8.37
.198275	7.20	.272892	8.53	38	.223758	6.97	.303322	8.37
.198707	7.18	.273404	8.53	39	.224176	6.95	.303824	8.35
.199138	7.18	.273916	8.53	40	.224593	6.97	.304325	8.37
9.199569	7.18	9.274428	8.53	41	9.225011	6.95	9.304827	8.35
.200000	7.17	.274940	8.53	42	.225428	6.95	.305328	8.37
.200430	7.18	.275452	8.52	43	.225845	6.95	.305830	8.35
.200861	7.17	.275963	8.52	44	.226262	6.93	.306331	8.35
.201291	7.15	.276474	8.53	45	.226678	6.95	.306832	8.35
.201720	7.17	.276986	8.50	46	.227095	6.93	.307333	8.33
.202150	7.15	.277496	8.52	47	.227511	6.93	.307833	8.35
.202579	7.15	.278007	8.52	48	.227927	6.92	.308334	8.33
.203008	7.15	.278518	8.50	49	.228342	6.93	.308834	8 33
.203437	7.15	.279028	8.50	50	.228758	6.92	.309334	8.33
9.203866	7.13	9.279538	8.50	51	9.229173	6.92	9.309834	8.33
.204294	7.15	.280048	8.50	52	.229588	6.92	.310334	8.33
.204723	7.13	.280558	8.50	53	.230003	6.92	.310834	8.32
.205151	7 12	.281068.	8.48	54	.230418	6.90	.311333	8.32
.205578	7.13	.281577	8.50	55	.230832	6.90	.311832	8.32
.206006	7.13	.282087	8.48	56	.231246	6.90	312331	8.32
.206433	7 12	.282596	8.48	57	.231660	6.90	.312830	8.32
206860	7.12	.283105	8.48	58	232074	6.88	.313329	8.32
207287	7.12	283614	8.47	59	.232487	6.90	.313828	8.30
9.207714	7.10	9.284122	8.48	60	9.232901	6.88	9.314328	8.3

34°					35°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.232901	6.88	9.314326	8.32	0	9.257314	6.67	9.343949	8.15
1	.233314	6.88	.314825	8.30	1	.257714	6.68	.344438	8.15
2	.233727	6.87	.315323	8.30	2	.258115	6.67	.344927	8.15
3	.234139	6.88	.315821	8.30	3	.258515	6.67	.345416	8.13
4	.234552	6.87	.316319	8.30	4	.258915	6.65	.345904	8.15
5	.234964	6.87	.316817	8.28	5	.259314	6.67	.346393	8.13
6	.235376	6.87	.317314	8.28	6	.259714	6.65	.346881	8.13
7	.235788	6.85	.317811	8.30	7	.260113	6.65	.347369	8.13
8	.236199	6.87	.318309	8.28	8	.260512	6.65	.347857	8.13
9	.236611	6.85	.318806	8.28	9	.260911	6.65	.348345	8.15
10	.237022	6.85	.319303	8.27	10	.261310	6.65	.348833	8.13
11	9.237433	6.85	9.319799	8.28	11	9.261709	6.63	9.349321	8.12
12	.237844	6.83	.320296	8.27	12	.262107	6.63	.349808	8.12
13	.238254	6.85	.320792	8.28	13	.262505	6.63	.350295	8.12
14	.238665	6.83	.321289	8.27	14	.262903	6.63	.350782	8.12
15	.239075	6.83	.321785	8.27	15	.263301	6.62	.351269	8.12
16	.239485	6.82	.322281	8.25	16	.263698	6.63	.351756	8.12
17	.239894	6.83	.322776	8.27	17	.264096	6.62	.352243	8.12
18	.240304	6.82	.323272	8.27	18	.264493	6.62	.352730	8.10
19	.240713	6.82	.323768	8.25	19	.264890	6 62	.353216	8.10
20	.241122	6.82	.324263	8.25	20	.265287	6.60	.353702	8.10
21	9.241531	6.82	9.324758	8.25	21	9.265683	6.62	9.354188	8.10
22	.241940	6.82	.325253	8.25	22	.266080	6.60	.354674	8.10
23	.242348	6.80	.325748	8.25	23	.266476	6.60	.355160	8.10
24	.242756	6.80	.326243	8.23	24	.266872	6.58	.355646	8.08
25	.243164	6.80	.326737	8.25	25	.267267	6.60	.356131	8.10
26	.243572	6.80	.327232	8.23	26	.267663	6.58	.356617	8.08
27	.243980	6.78	.327726	8.23	27	.268058	6.58	.357102	8.08
28	.244387	6.78	.328220	8.23	28	.268453	6.58	.357587	8.08
29	.244794	6.78	.328714	8.22	29	.268848	6.58	.358072	8.08
30	.245201	6.78	.329207	8.23	30	.269243	6.58	.358557	8.08
31	9.245608	6.77	9.329701	8.23	31	9.269638	6.57	9.359042	8.07
32	.246014	6.78	.330195	8.22	32	.270032	6.57	.359526	8.08
33	.246421	6.77	.330688	8.22	33	.270426	6.57	.360011	8.07
34	.246827	6.77	.331181	8.22	34	.270820	6.57	.360495	8.07
35	.247233	6.77	.331674	8.23	35	.271214	6.57	.360979	8.07
36	.247639	6.75	.332167	8.20	36	.271608	6.55	.361463	8.07
37	.248044	6.75	.332659	8.22	37	.272001	6.55	.361947	8.07
38	.248449	6.75	.333152	8.20	38	.272394	6.55	.362431	8.05
39	.248854	6.75	.333644	8.22	39	.272787	6.55	.362914	8.07
40	.249259	6.75	.334137	8.20	40	.273180	6.53	.363398	8.05
41	9.249664	6.73	9.334629	8.20	41	9.273572	6.55	9.363881	8.05
42	.250068	6.75	.335121	8.18	42	.273965	6.53	.364364	8.05
43	.250473	6.73	.335612	8.20	43	.274357	6.53	.364847	8.05
44	.250877	6.73	.336104	8.18	44	.274749	6.53	.365330	8.05
45	.251281	6.72	.336595	8.20	45	.275141	6.52	.365813	8.03
46	.251684	6.73	.337087	8.18	46	.275532	6.53	.366295	8.05
47	.252088	6.72	.337578	8.18	47	.275924	6.52	.366778	8.03
48	.252491	6.72	.338069	8.18	48	.276315	6.52	.367260	8.03
49	.252894	6.72	.338560	8.17	49	.276706	6.52	.367742	8.03
50	.253297	6.70	.339050	8.18	50	.277097	6.52	.368224	8.03
51	9.253699	6.72	9.339541	8.17	51	9.277488	6.50	9.368706	8.03
52	.254102	6.70	.340031	8.18	52	.277878	6.50	.369188	8.03
53	.254504	6.70	.340522	8.17	53	.278268	6.50	.369670	8.02
54	.254906	6.70	.341012	8.17	54	.278658	6.50	.370151	8.02
55	.255308	6.68	.341502	8.15	55	.279048	6.50	.370632	8.03
56	.255709	6.70	.341991	8.17	56	.279438	6.48	.371114	8.02
57	.256111	6.68	.342481	8.17	57	.279827	6.50	.371595	8.02
58	.256512	6.68	.342971	8.15	58	.280217	6.48	.372076	8.00
59	.256913	6.68	.343460	8.15	59	.280606	6.48	.372556	8.02
60	9.257314	6.67	9.343949	8.15	60	9.280995	6.47	9.373037	8.02

60°					61°			
Vers.	D. 1".	Ex. sec.	D. 1".	'	Vers.	D. 1".	Ex. sec.	D.1".
9.698970	3.65	10.000000	7.30	0	9.711968	3.57	10.026397	7.37
.699189	3.63	.000438	7.28	1	.712182	3.58	.026839	7.37
.699407	3.65	.000875	7.30	2	.712397	3.57	.027281	7.38
.699626	3.65	.001313	7.30	3	.712611	3.57	.027724	7.38
.699845	3.63	.001751	7.30	4	.712825	3.57	.028167	7.37
.700063	3.65	.002189	7.30	5	.713039	3.57	.028609	7.38
.700282	3.63	.002627	7.30	6	.713253	3.57	.029052	7.38
.700500	3.63	.003065	7.30	7	.713467	3.57	.029495	7.38
.700718	3.63	.003503	7.32	8	.713681	3.57	.029938	7.38
.700936	3.63	.003942	7.30	9	.713895	3.57	.030381	7.40
.701154	3.63	.004380	7.30	10	.714109	3.57	.030825	7.38
9.701372	3.63	10.004818	7.32	11	9.714323	3.55	10.031268	7.38
.701590	3.63	.005257	7.30	12	.714536	3.57	.031711	7.40
.701808	3.63	.005695	7.32	13	.714750	3.55	.032155	7.38
.702026	3.63	.006134	7.32	14	.714963	3.57	.032598	7.40
.702244	3.63	.006573	7.32	15	.715177	3.55	.033042	7.40
.702462	3.62	.007012	7.30	16	.715390	3.55	.033486	7.38
.702679	3.63	.007450	7.32	17	.715603	3.57	.033929	7.40
.702897	3.62	.007889	7.32	18	.715817	3.55	.034373	7.40
.703114	3.63	.008328	7.32	19	.716030	3.55	.034817	7.40
.703332	3.62	.008767	7.33	20	.716243	3.55	.035261	7.40
9.703549	3.62	10.009207	7.32	21	9.716456	3.55	10.035705	7.42
.703766	3.62	.009646	7.32	22	.716669	3.55	.036150	7.40
.703983	3.62	.010085	7.33	23	.716882	3.55	.036594	7.40
.704200	3.62	.010525	7.32	24	.717095	3.53	.037038	7.42
.704417	3.62	.010964	7.33	25	.717307	3.55	.037483	7.42
.704634	3.62	.011404	7.32	26	.717520	3.53	.037928	7.40
.704851	3.62	.011843	7.33	27	.717732	3.55	.038372	7.42
.705068	3.62	.012283	7.33	28	.717945	3.53	.038817	7.42
.705285	3.60	.012723	7.33	29	.718157	3.55	.039262	7.42
.705501	3.62	.013163	7.33	30	.718370	3.53	.039707	7.42
9.705718	3.62	10.013603	7.33	31	9.718582	3.53	10.040152	7.42
.705935	3.60	.014043	7.33	32	.718794	3.55	.040597	7.42
.706151	3.60	.014483	7.33	33	.719007	3.53	.041042	7.43
.706367	3.62	.014923	7.33	34	.719219	3.53	.041488	7.42
.706584	3.60	.015363	7.35	35	.719431	3.53	.041933	7.43
.706800	3.60	.015804	7.33	36	.719643	3.53	.042379	7.42
.707016	3.60	.016244	7.33	37	.719855	3.52	.042824	7.43
.707232	3.60	.016684	7.33	38	.720066	3.53	.043270	7.43
.707448	3.60	.017125	7.35	39	.720278	3.53	.043716	7.43
.707664	3.60	.017566	7.35	40	.720490	3.52	.044162	7.43
9.707880	3.60	10.018007	7.33	41	9.720701	3.53	10.044608	7.43
.708096	3.58	.018447	7.35	42	.720913	3.52	.045054	7.43
.708311	3.60	.018888	7.35	43	.721124	3.53	.045500	7.43
.708527	3.60	.019329	7.35	44	.721336	3.52	.045946	7.45
.708743	3.58	.019770	7.37	45	.721547	3.52	.046393	7.43
.708958	3.60	.020212	7.35	46	.721758	3.53	.046839	7.45
.709174	3.58	.020653	7.35	47	.721970	3.52	.047286	7.43
.709389	3.58	.021094	7.35	48	.722181	3.52	.047732	7.45
.709604	3.58	.021535	7.37	49	.722392	3.52	.048179	7.45
.709819	3.58	.021977	7.37	50	.722603	3.52	.048626	7.45
9.710035	3.58	10.022419	7.35	51	9.722814	3.50	10.049073	7.45
.710250	3.58	.022860	7.37	52	.723024	3.52	.049520	7.45
.710465	3.58	.023302	7.37	53	.723235	3.52	.049967	7.45
.710680	3.58	.023744	7.37	54	.723446	3.52	.050414	7.45
.710895	3.57	.024186	7.37	55	.723657	3.50	.050861	7.47
.711109	3.58	.024628	7.37	56	.723867	3.52	.051309	7.45
.711324	3.58	.025070	7.37	57	.724078	3.50	.051758	7.4
.711539	3.57	.025512	7.37	58	.724288	3.50	.052204	7.
.711753	3.58	.025954	7.38	59	.724498	3.52	.052652	7.
.711968	3.57	10.026397	7.37	60	9.724709	3.50	10.053099	

62°					63°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.
0	9.724709	3.50	10.053099	7.47	0	9.737200	3.43	10.080153
1	.724919	3.50	.053547	7.47	1	.737406	3.43	.080608
2	.725129	3.50	.053995	7.47	2	.737612	3.43	.081062
3	.725339	3.50	.054443	7.48	3	.737818	3.43	.081516
4	.725549	3.50	.054892	7.47	4	.738024	3.43	.081971
5	.725759	3.50	.055340	7.47	5	.738230	3.43	.082425
6	.725969	3.50	.055788	7.48	6	.738436	3.43	.082880
7	.726179	3.48	.056237	7.47	7	.738642	3.42	.083335
8	.726388	3.50	.056685	7.48	8	.738847	3.43	.083790
9	.726598	3.50	.057134	7.48	9	.739053	3.42	.084245
10	.726808	3.48	.057583	7.48	10	.739258	3.43	.084700
11	9.727017	3.50	10.058032	7.48	11	9.739464	3.42	10.085155
12	.727227	3.48	.058481	7.48	12	.739669	3.43	.085611
13	.727436	3.48	.058930	7.48	13	.739875	3.42	.086066
14	.727645	3.50	.059379	7.48	14	.740080	3.42	.086522
15	.727855	3.48	.059828	7.50	15	.740285	3.42	.086977
16	.728064	3.48	.060278	7.48	16	.740490	3.42	.087433
17	.728273	3.48	.060727	7.50	17	.740695	3.42	.087889
18	.728482	3.48	.061177	7.48	18	.740900	3.42	.088345
19	.728691	3.48	.061626	7.50	19	.741105	3.42	.088801
20	.728900	3.48	.062076	7.50	20	.741310	3.42	.089258
21	9.729109	3.47	10.062526	7.50	21	9.741515	3.40	10.089714
22	.729317	3.48	.062976	7.50	22	.741719	3.42	.090171
23	.729526	3.48	.063426	7.50	23	.741924	3.42	.090627
24	.729735	3.47	.063876	7.52	24	.742129	3.40	.091084
25	.729943	3.48	.064327	7.50	25	.742333	3.42	.091541
26	.730152	3.47	.064777	7.50	26	.742538	3.40	.091998
27	.730360	3.48	.065227	7.52	27	.742742	3.40	.092455
28	.730569	3.47	.065678	7.52	28	.742946	3.40	.092912
29	.730777	3.47	.066129	7.52	29	.743150	3.42	.093370
30	.730985	3.47	.066580	7.50	30	.743355	3.40	.093827
31	9.731193	3.47	10.067030	7.53	31	9.743559	3.40	10.094285
32	.731401	3.47	.067482	7.52	32	.743762	3.40	.094743
33	.731609	3.47	.067933	7.52	33	.743967	3.40	.095200
34	.731817	3.47	.068384	7.52	34	.744171	3.40	.095658
35	.732025	3.47	.068835	7.53	35	.744375	3.38	.096116
36	.732233	3.47	.069287	7.52	36	.744578	3.40	.096575
37	.732441	3.45	.069738	7.53	37	.744782	3.40	.097033
38	.732648	3.47	.070190	7.53	38	.744986	3.38	.097491
39	.732856	3.47	.070642	7.52	39	.745189	3.40	.097950
40	.733064	3.45	.071093	7.53	40	.745393	3.38	.098408
41	9.733271	3.45	10.071545	7.55	41	9.745596	3.40	10.098867
42	.733478	3.47	.071998	7.53	42	.745800	3.38	.099326
43	.733686	3.45	.072450	7.53	43	.746003	3.38	.099785
44	.733893	3.45	.072902	7.53	44	.746206	3.38	.100244
45	.734100	3.45	.073354	7.55	45	.746409	3.40	.100704
46	.734307	3.47	.073807	7.55	46	.746613	3.38	.101163
47	.734515	3.43	.074260	7.53	47	.746816	3.38	.101623
48	.734721	3.45	.074712	7.55	48	.747019	3.38	.102082
49	.734928	3.45	.075165	7.55	49	.747222	3.37	.102542
50	.735135	3.45	.075618	7.55	50	.747424	3.38	.103002
51	9.735342	3.45	10.076071	7.55	51	9.747627	3.38	10.103462
52	.735549	3.43	.076524	7.55	52	.747830	3.38	.103922
53	.735755	3.45	.076977	7.57	53	.748033	3.37	.104382
54	.735962	3.45	.077431	7.55	54	.748235	3.33	.104843
55	.736169	3.43	.077884	7.57	55	.748438	3.37	.105303
56	.736375	3.43	.078338	7.57	56	.748640	3.38	.105764
57	.736581	3.45	.078792	7.55	57	.748843	3.37	.106224
8	.736788	3.43	.079245	7.57	58	.749045	3.37	.10668
	.736994	3.43	.079699	7.57	59	.749247	3.37	.1071
	9.737200	3.43	10.080153	7.58	60	9.749449	3.38	10.107

64°					65°			
Vers.	D. 1".	Ex. sec.	D 1".	′	Vers.	D. 1".	Ex. sec.	D.1".
9.749449	3.38	10.107607	7.70	0	9.761463	3.30	10.135515	7.82
.749652	3.37	.108069	7.68	1	.761661	3.32	.135984	7.83
.749854	3.37	.108530	7.70	2	.761860	3.30	.136454	7.82
.750056	3.37	.108992	7.68	3	.762058	3.30	.136923	7.83
.750258	3.35	.109453	7.70	4	.762256	3.30	.137393	7.83
.750459	3.37	.109915	7.70	5	.762454	3.30	.137863	7.83
.750661	3.37	.110377	7.70	6	.762652	3.30	.138333	7.83
.750863	3.37	.110839	7.70	7	.762850	3.28	.138803	7.83
.751065	3.35	.111301	7.70	8	.763047	3.30	.139273	7.85
.751266	3.37	.111763	7.72	9	.763245	3.30	.139744	7.83
.751468	3.35	.112226	7.70	10	.763443	3.30	.140214	7.85
9.751669	3.37	10.112688	7.72	11	9.763641	3.28	10.140685	7.85
.751871	3.35	.113151	7.72	12	.763838	3.30	.141156	7.85
.752072	3.35	.113614	7.72	13	.764036	3.28	.141627	7.85
.752273	3.37	.114077	7.72	14	.764233	3.28	.142098	7.85
.752475	3.35	.114540	7.72	15	.764430	3.30	.142569	7.87
.752676	3.35	.115003	7.72	16	.764628	3.28	.143041	7.85
.752877	3.35	.115466	7.72	17	.764825	3.28	.143512	7.87
.753078	3.35	.115929	7.73	18	.765022	3.28	.143984	7.87
.753279	3.35	.116393	7.73	19	.765219	3.28	.144456	7.87
.753480	3.35	.116857	7.73	20	.765416	3.28	.144928	7.87
9.753681	3.33	10.117321	7.73	21	9.765613	3.28	10.145400	7.87
.753881	3.35	.117785	7.73	22	.765810	3.28	.145872	7.88
.754082	3.35	.118249	7.73	23	.766007	3.28	.146345	7.88
.754283	3.33	.118713	7.73	24	.766204	3.28	.146818	7.87
.754483	3.35	.119177	7.75	25	.766401	3.27	.147290	7.88
.754684	3.33	.119642	7.73	26	.766597	3.28	.147763	7.88
.754884	3.35	.120106	7.75	27	.766794	3.28	.148236	7.90
.755085	3.33	.120571	7.75	28	.766991	3.27	.148710	7.88
.755285	3.33	.121036	7.75	29	.767187	3.28	.149183	7.90
.755485	3.33	.121501	7.75	30	.767384	3.27	.149657	7.88
9.755685	3.35	10.121966	7.75	31	9.767580	3.27	10.150130	7.90
.755886	3.33	.122431	7.77	32	.767776	3.27	.150604	7.90
.756086	3.33	.122897	7.75	33	.767972	3.28	.151078	7.90
.756286	3.33	.123362	7.77	34	.768169	3.27	.151552	7.92
.756486	3.32	.123828	7.77	35	.768365	3.27	.152027	7.90
.756685	3.33	.124294	7.77	36	.768561	3.27	.152501	7.92
.756885	3.33	.124760	7.77	37	.768757	3.27	.152976	7.90
.757085	3.33	.125226	7.77	38	.768953	3.27	.153450	7.92
.757285	3.32	.125692	7.77	39	.769149	3.25	.153925	7.92
.757484	3.33	.126158	7.78	40	.769344	3.27	.154400	7.93
9.757684	3.32	10.126625	7.78	41	9.769540	3.27	10.154876	7.92
.757883	3.33	.127092	7.77	42	.769736	3.25	.155351	7.92
.758083	3.32	.127558	7.78	43	.769931	3.27	.155826	7.93
.758282	3.32	.128025	7.78	44	.770127	3.27	.156302	7.93
.758481	3.33	.128492	7.80	45	.770323	3.25	.156778	7.93
.758681	3.32	.128960	7.78	46	.770518	3.25	.157254	7.93
.758880	3.32	.129427	7.78	47	.770713	3.27	.157730	7.93
.759079	3.32	.129894	7.80	48	.770909	3.25	.158206	7.95
.759278	3.32	.130362	7.80	49	.771104	3.25	.158683	7.93
.759477	3.32	.130830	7.80	50	.771299	3.25	.159159	7.95
9.759676	3.32	10.131298	7.80	51	9.771494	3.25	10.159636	7.95
.759875	3.30	.131766	7.80	52	.771689	3.25	.160113	7.95
.760073	3.32	132234	7.80	53	.771884	3.25	.160590	7.95
.760272	3.32	.132702	7.80	54	.772079	3.25	.161067	7.97
.760471	3.30	.133170	7.82	55	.772274	3.25	.161545	7.95
.760669	3.32	.133639	7.82	56	.772469	3.25	.162022	7.97
.760868	3.30	.134108	7.82	57	.772664	3.23	.162500	7.97
.761066	3.32	.134577	7.82	58	.772858	3.25	.162978	7.
.761265	3.30	.135046	7.82	59	.773053	3.25	.163456	7
9.761463	3.30	10.135515	7.82	60	9.773248	3.23	10.163936	

66°					67			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.
0	9.773248	3.23	10.163934	7.98	0	9.784809	3.18	10.192931
1	.773442	3.23	.164413	7.97	1	.785000	3.18	.193420
2	.773636	3.25	.164891	7.98	2	.785191	3.17	.193908
3	.773831	3.23	.165370	7.98	3	.785381	3.18	.194397
4	.774025	3.23	.165849	7.98	4	.785572	3.18	.194886
5	.774219	3.25	.166328	7.98	5	.785763	3.17	.195376
6	.774414	3.23	.166807	7.98	6	.785953	3.18	.195865
7	.774608	3.23	.167286	8.00	7	.786144	3.17	.196355
8	.774802	3.23	.167766	7.98	8	.786334	3.17	.196845
9	.774996	3.23	.168245	8.00	9	.786524	3.18	.197335
10	.775190	3.23	.168725	8.00	10	.786715	3.17	.197825
11	9.775384	3.22	10.169205	8.00	11	9.786905	3.17	10.198315
12	.775577	3.23	.169685	8.00	12	.787095	3.17	.198806
13	.775771	3.23	.170165	8.02	13	.787285	3.17	.199297
14	.775965	3.23	.170646	8.02	14	.787475	3.17	.199788
15	.776159	3.22	.171127	8.00	15	.787665	3.17	.200279
16	.776352	3.23	.171607	8.02	16	.787855	3.17	.200770
17	.776546	3.22	.172088	8.02	17	.788045	3.17	.201262
18	.776739	3.23	.172569	8.03	18	.788235	3.17	.201753
19	.776933	3.22	.173051	8.02	19	.788425	3.15	.202245
20	.777126	3.22	.173532	8.03	20	.788614	3.17	.202737
21	9.777319	3.22	10.174014	8.03	21	9.788804	3.15	10.203229
22	.777512	3.22	.174496	8.03	22	.788993	3.17	.203722
23	.777705	3.23	.174978	8.03	23	.789183	3.15	.204215
24	.777899	3.22	.175460	8.03	24	.789372	3.17	.204707
25	.778092	3.22	.175942	8.05	25	.789562	3.15	.205200
26	.778285	3.20	.176425	8.03	26	.789751	3.15	.205694
27	.778477	3.22	.176907	8.05	27	.789940	3.17	.206187
28	.778670	3.22	.177390	8.05	28	.790130	3.15	.206681
29	.778863	3.22	.177873	8.05	29	.790319	3.15	.207174
30	.779056	3.20	.178356	8.05	30	.790508	3.15	.207668
31	9.779248	3.22	10.178839	8.07	31	9.790697	3.15	10.208162
32	.779441	3.22	.179323	8.07	32	.790886	3.15	.208657
33	.779634	3.20	.179807	8.05	33	.791075	3.15	.209151
34	.779826	3.20	.180290	8.07	34	.791264	3.15	.209646
35	.780018	3.22	.180774	8.08	35	.791453	3.13	.210141
36	.780211	3.20	.181259	8.07	36	.791641	3.15	.210636
37	.780403	3.20	.181743	8.07	37	.791830	3.15	.211131
38	.780595	3.20	.182227	8.08	38	.792019	3.13	.211627
39	.780787	3.22	.182712	8.08	39	.792207	3.15	.212123
40	.780980	3.20	.183197	8.08	40	.792396	3.13	.212618
41	9.781172	3.20	10.183682	8.08	41	9.792584	3.13	10.213115
42	.781364	3.20	.184167	8.10	42	.792772	3.15	.213611
43	.781556	3.18	.184653	8.08	43	.792961	3.13	.214107
44	.781747	3.20	.185138	8.10	44	.793149	3.13	.214604
45	.781939	3.20	.185624	8.10	45	.793337	3.13	.215101
46	.782131	3.20	.186110	8.10	46	.793525	3.15	.215598
47	.782323	3.18	.186596	8.10	47	.793714	3.13	.216095
48	.782514	3.20	.187082	8.10	48	.793902	3.13	.216593
49	.782706	3.18	.187568	8.12	49	.794090	3.12	.217090
50	.782897	3.20	.188055	8.12	50	.794277	3.13	.217588
51	9.783089	3.18	10.188542	8.12	51	9.794465	3.13	10.218086
52	.783280	3.18	.189029	8.12	52	.794653	3.13	.218585
53	.783471	3.20	.189516	8.12	53	.794841	3.12	.219083
54	.783663	3.18	.190003	8.13	54	.795028	3.13	.219582
55	.783854	3.18	.190491	8.12	55	.795216	3.13	.220081
56	.784045	3.18	.190978	8.13	56	.795404	3.12	.220580
57	.784236	3.18	.191466	8.13	57	.795591	3.13	.221079
58	.784427	3.18	.191954	8.15	58	.795779	3.12	.22157
59	.784618	3.18	.192443	8.13	59	.795966	3.12	.2220
60	9.784809	3.18	10.192931	8.15	60	9.796153	3.13	10.222

68°

′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.796153	3.13	10.222578	8.33
1	.796341	3.12	.223078	8.33
2	.796528	3.12	.223578	8.35
3	.796715	3.12	.224079	8.33
4	.796902	3.12	.224579	8.35
5	.797089	3.12	.225080	8.35
6	.797276	3.12	.225581	8.37
7	.797463	3.12	.226083	8.35
8	.797650	3.12	.226584	8.37
9	.797837	3.10	.227086	8.37
10	.798023	3.12	.227588	8.37
11	9.798210	3.12	10.228090	8.37
12	.798397	3.10	.228592	8.38
13	.798583	3.12	.229095	8.38
14	.798770	3.10	.229598	8.38
15	.798956	3.10	.230101	8.38
16	.799142	3.12	.230604	8.38
17	.799329	3.10	.231107	8.40
18	.799515	3.10	.231611	8.40
19	.799701	3.10	.232115	8.40
20	.799887	3.12	.232619	8.40
21	9.800074	3.10	10.233123	8.40
22	.800260	3.10	.233627	8.42
23	.800446	3.08	.234132	8.42
24	.800631	3.10	.234637	8.42
25	.800817	3.10	.235142	8.42
26	.801003	3.10	.235647	8.43
27	.801189	3.10	.236153	8.42
28	.801375	3.08	.236658	8.43
29	.801560	3.10	.237164	8.43
30	.801746	3.08	.237670	8.45
31	9.801931	3.10	10.238177	8.43
32	.802117	3.08	.238683	8.45
33	.802302	3.08	.239190	8.45
34	.802487	3.10	.239697	8.45
35	.802673	3.08	.240204	8.47
36	.802858	3.08	.240712	8.45
37	.803043	3.08	.241219	8.47
38	.803228	3.08	.241727	8.47
39	.803413	3.06	.242235	8.48
40	.803598	3.08	.242744	8.47
41	9.803783	3.08	10.243252	8.48
42	.803968	3.08	.243761	8.48
43	.804153	3.08	.244270	8.48
44	.804338	3.07	.244779	8.50
45	.804522	3.08	.245289	8.48
46	.804707	3.08	.245798	8.50
47	.804892	3.07	.246308	8.50
48	.805076	3.08	.246818	8.52
49	.805261	3.07	.247329	8.50
50	.805445	3.07	.247839	8.52
51	9.805629	3.08	10.248350	8.52
52	.805814	3.07	.248861	8.52
53	.805998	3.07	.249372	8.52
54	.806182	3.07	.249883	8.53
55	.806366	3.07	.250395	8.53
56	.806550	3.07	.250907	8.53
57	.806734	3.07	.251419	8.55
58	.806918	3.07	.251932	8.53
59	.807102	3.07	.252444	8.55
60	9.807286	3.07	10.252957	8.55

69°

′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.807286	3.07	10.252957	8.55
1	.807470	3.07	.253470	8.55
2	.807654	3.05	.253983	8.57
3	.807837	3.07	.254497	8.55
4	.808021	3.05	.255010	8.57
5	.808204	3.07	.255524	8.58
6	.808388	3.05	.256039	8.57
7	.808571	3.07	.256553	8.58
8	.808755	3.05	.257068	8.57
9	.808938	3.05	.257582	8.60
10	.809121	3.07	.258098	8.58
11	9.809305	3.05	10.258613	8.60
12	.809488	3.05	.259129	8.58
13	.809671	3.05	.259644	8.60
14	.809854	3.05	.260160	8.62
15	.810037	3.05	.260677	8.60
16	.810220	3.05	.261193	8.62
17	.810403	3.03	.261710	8.62
18	.810585	3.05	.262227	8.62
19	.810768	3.05	.262744	8.63
20	.810951	3.05	.263262	8.62
21	9.811134	3.03	10.263779	8.63
22	.811316	3.05	.264297	8.63
23	.811499	3.03	.264815	8.65
24	.811681	3.05	.265334	8.65
25	.811864	3.03	.265853	8.63
26	.812046	3.03	.266371	8.67
27	.812228	3.03	.266891	8.65
28	.812410	3.05	.267410	8.67
29	.812593	3.03	.267930	8.65
30	.812775	3.03	.268449	8.68
31	9.812957	3.03	10.268970	8.67
32	.813139	3.03	.269490	8.68
33	.813321	3.03	.270011	8.67
34	.813503	3.03	.270531	8.68
35	.813685	3.02	.271052	8.70
36	.813866	3.03	.271574	8.68
37	.814048	3.03	.272095	8.70
38	.814230	3.02	.272617	8.70
39	.814411	3.03	.273139	8.72
40	.814593	3.03	.273662	8.70
41	9.814775	3.02	10.274184	8.72
42	.814956	3.02	.274707	8.72
43	.815137	3.03	.275230	8.72
44	.815319	3.02	.275753	8.73
45	.815500	3.02	.276277	8.73
46	.815681	3.02	.276801	8.73
47	.815862	3.03	.277325	8.73
48	.816044	3.02	.277849	8.75
49	.816225	3.02	.278374	8.75
50	.816406	3.02	.278899	8.75
51	9.816587	3.00	10.279424	8.75
52	.816767	3.02	.279949	8.77
53	.816948	3.02	.280475	8.75
54	.817129	3.02	.281000	8.78
55	.817310	3.00	.281527	8.77
56	.817490	3.02	.282053	8.7
57	.817671	3.02	.282580	8.
58	.817852	3.00	.283106	8
59	.818032	3.02	.283634	
60	9.818213	3.00	10.284161	

70°					71°				
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.818213	3.00	10.284161	8.80	0	9.828938	2.95	10.316296	9.07
1	.818393	3.00	.284689	8.78	1	.829115	2.95	.316840	9.08
2	.818573	3.02	.285216	8.82	2	.829292	2.95	.317385	9.07
3	.818754	3.00	.285745	8.80	3	.829469	2.95	.317929	9.10
4	.818934	3.00	.286273	8.82	4	.829646	2.95	.318475	9.08
5	.819114	3.00	.286802	8.82	5	.829823	2.95	.319020	9.08
6	.819294	3.00	.287331	8.82	6	.830000	2.95	.319565	9.10
7	.819474	3.00	.287860	8.82	7	.830177	2.93	.320111	9.12
8	.819654	3.00	.288389	8.83	8	.830353	2.95	.320658	9.10
9	.819834	3.00	.288919	8.83	9	.830530	2.93	.321204	9.12
10	.820014	3.00	.289449	8.83	10	.830706	2.95	.321751	9.12
11	9.820194	3.00	10.289979	8.85	11	9.830883	2.93	10.322298	9.12
12	.820374	2.98	.290510	8.85	12	.831059	2.95	.322845	9.13
13	.820553	3.00	.291041	8.85	13	.831236	2.93	.323393	9.13
14	.820733	3.00	.291572	8.85	14	.831412	2.95	.323941	9.13
15	.820913	2.98	.292103	8.87	15	.831589	2.93	.324489	9.15
16	.821092	3.00	.292635	8.85	16	.831765	2.93	.325038	9.15
17	.821272	2.98	.293166	8.87	17	.831941	2.93	.325587	9.15
18	.821451	3.00	.293698	8.88	18	.832117	2.93	.326136	9.17
19	.821631	2.98	.294231	8.88	19	.832293	2.93	.326686	9.15
20	.821810	2.98	.294764	8.87	20	.832469	2.93	.327235	9.18
21	9.821989	2.98	10.295296	8.90	21	9.832645	2.93	10.327786	9.17
22	.822168	3.00	.295830	8.88	22	.832821	2.93	.328336	9.18
23	.822348	2.98	.296363	8.90	23	.832997	2.93	.328887	9.18
24	.822527	2.98	.296897	8.90	24	.833173	2.93	.329438	9.18
25	.822706	2.98	.297431	8.90	25	.833349	2.93	.329989	9.20
26	.822885	2.98	.297965	8.92	26	.833525	2.92	.330541	9.20
27	.823064	2.98	.298500	8.90	27	.833700	2.93	.331093	9.20
28	.823243	2.97	.299034	8.93	28	.833876	2.92	.331645	9.22
29	.823421	2.98	.299570	8.92	29	.834051	2.93	.332198	9.20
30	.823600	2.98	.300105	8.93	30	.834227	2.92	.332750	9.23
31	9.823779	2.98	10.300641	8.92	31	9.834402	2.93	10.333304	9.22
32	.823958	2.97	.301176	8.95	32	.834578	2.92	.333857	9.23
33	.824136	2.98	.301713	8.93	33	.834753	2.92	.334411	9.23
34	.824315	2.97	.302249	8.95	34	.834928	2.93	.334965	9.25
35	.824493	2.98	.302786	8.95	35	.835104	2.92	.335520	9.23
36	.824672	2.97	.303323	8.95	36	.835279	2.92	.336074	9.25
37	.824850	2.97	.303860	8.97	37	.835454	2.92	.336629	9.27
38	.825028	2.98	.304398	8 97	38	.835629	2.92	.337185	9.27
39	.825207	2.97	.304936	8.97	39	.835804	2.92	.337741	9.27
40	.825385	2.97	.305474	8.97	40	.835979	2.92	.338297	9.27
41	9.825563	2.97	10.306012	8.98	41	9.836154	2.92	10.338853	9.28
42	.825741	2.97	.306551	8.98	42	.836329	2.92	.339410	9.28
43	.825919	2.97	.307090	8.98	43	.836504	2.90	.339967	9.28
44	.826097	2.97	.307629	9.00	44	.836678	2.92	.340524	9.30
45	.826275	2.97	.308169	8.98	45	.836853	2.92	.341082	9.30
46	.826453	2.97	.308708	9.02	46	.837028	2.90	.341640	9.30
47	.826631	2.97	.309249	9.00	47	.837202	2.88	.342198	9.30
48	.826809	2.97	.309789	9.02	48	.837377	2.90	.342756	9.32
49	.826987	2.95	.310330	9.02	49	.837551	2.92	.343315	9.33
50	.827164	2.97	.310871	9.02	50	.837726	2.90	.343875	9.32
51	9.827342	2.95	10.311412	9.02	51	9.837900	2.92	10.344434	9.33
52	.827519	2.97	.311953	9.03	52	.838075	2.90	.344994	9.33
53	.827697	2.95	.312495	9.03	53	.838249	2.90	.345554	9.35
54	.827874	2.97	.313037	9.05	54	.838423	2.90	.346115	9.35
55	.828052	2.95	.313580	9.03	55	.838597	2.90	.346676	9.35
56	.828229	2.95	.314122	9.05	56	.838771	2.90	.347237	9.35
	.828406	2.97	.314665	9.07	57	.838945	2.90	.347798	[illegible]
	.828584	2.95	.315209	9.05	58	.839119	2.90	.348360	[illegible]
	828761	2.95	.315752	9.07	59	.839293	2.90	.348922	[illegible]
	828938	2.95	10.316296	9.07	60	9.839467	2.90	10.349485	[illegible]

48°					49°			
Vers.	D. 1".	Ex. sec.	D. 1".	′	Vers.	D. 1".	Ex. sec.	D. 1".
9.519657	4.72	9.694146	7.07	0	9.536484	4.62	9.719541	7.05
.519940	4.73	.694570	7.07	1	.536761	4.62	.719964	7.03
.520224	4.72	.694994	7.07	2	.537038	4.62	.720386	7.05
.520507	4.73	.695418	7.07	3	.537315	4.62	.720809	7.03
.520791	4.72	.695842	7.07	4	.537592	4.62	.721231	7.03
.521074	4.72	.696266	7.05	5	.537869	4.60	.721653	7.05
.521357	4.72	.696689	7.07	6	.538145	4.62	.722076	7.03
.521640	4.72	.697113	7.07	7	.538422	4.60	.722498	7.05
.521923	4.72	.697537	7.07	8	.538698	4.60	.722921	7.03
.522206	4.70	.697961	7.07	9	.538974	4.62	.723343	7.03
.522488	4.72	.698385	7.07	10	.539251	4.60	.723765	7.05
9.522771	4.72	9.698809	7.05	11	9.539527	4.60	9.724188	7.03
.523054	4.70	.699232	7.07	12	.539803	4.60	.724610	7.03
.523336	4.70	.699656	7.07	13	.540079	4.58	.725032	7.03
.523618	4.70	.700080	7.05	14	.540354	4.60	.725454	7.05
.523900	4.70	.700503	7.07	15	.540630	4.60	.725877	7.03
.524182	4.70	.700927	7.05	16	.540906	4.58	.726299	7.03
.524464	4.70	.701350	7.07	17	.541181	4.58	.726721	7.03
.524746	4.70	.701774	7.07	18	.541456	4.60	.727143	7.03
.525028	4.68	.702198	7.05	19	.541732	4.58	.727565	7.05
.525309	4.70	.702621	7.07	20	.542007	4.58	.727988	7.03
9.525591	4.68	9.703045	7.05	21	9.542282	4.58	9.728410	7.03
.525872	4.68	.703468	7.05	22	.542557	4.58	.728832	7.03
.526153	4.70	.703891	7.07	23	.542832	4.57	.729254	7.03
.526435	4.68	.704315	7.05	24	.543106	4.58	.729676	7.03
.526716	4.68	.704738	7.07	25	.543381	4.57	.730098	7.03
.526997	4.67	.705162	7.05	26	.543655	4.58	.730520	7.03
.527277	4.68	.705585	7.05	27	.543930	4.57	.730942	7.03
.527558	4.68	.706008	7.05	28	.544204	4.57	.731364	7.03
.527839	4.67	.706431	7.07	29	.544478	4.57	.731786	7.03
.528119	4.68	.706855	7.05	30	.544752	4.57	.732208	7.03
9.528400	4.67	9.707278	7.05	31	9.545026	4.57	9.732630	7.03
.528680	4.67	.707701	7.05	32	.545300	4.57	.733052	7.03
.528960	4.67	.708124	7.05	33	.545574	4.57	.733474	7.03
.529240	4.67	.708547	7.07	34	.545848	4.55	.733896	7.02
.529520	4.67	.708971	7.05	35	.546121	4.57	.734317	7.03
.529800	4.67	.709394	7.05	36	.546395	4.55	.734739	7.03
.530080	4.65	.709817	7.05	37	.546668	4.55	.735161	7.03
.530359	4.67	.710240	7.05	38	.546941	4.55	.735583	7.03
.530639	4.65	.710663	7.05	39	.547214	4.55	.736005	7.03
.530918	4.67	.711086	7.05	40	.547487	4.55	.736427	7.02
9.531198	4.65	9.711509	7.05	41	9.547760	4.55	9.736848	7.03
.531477	4.65	.711932	7.05	42	.548033	4.55	.737270	7.03
.531756	4.65	.712355	7.05	43	.548306	4.55	.737692	7.03
.532035	4.65	.712778	7.03	44	.548579	4.53	.738114	7.02
.532314	4.63	.713200	7.05	45	.548851	4.55	.738535	7.03
.532592	4.65	.713623	7.05	46	.549124	4.53	.738957	7.03
.532871	4.65	.714046	7.05	47	.549396	4.53	.739379	7.02
.533150	4.63	.714469	7.05	48	.549668	4.53	.739800	7.03
.533428	4.63	.714892	7.05	49	.549940	4.53	.740222	7.03
.533706	4.65	.715315	7.03	50	.550212	4.53	.740644	7.02
9.533985	4.63	9.715737	7.05	51	9.550484	4.53	9.741065	7.03
.534263	4.63	.716160	7.05	52	.550756	4.53	.741487	7.02
.534541	4.63	.716583	7.03	53	.551028	4.52	.741908	7.03
.534819	4.63	.717005	7.05	54	.551299	4.53	.742330	7.02
.535097	4.62	.717428	7.05	55	.551571	4.52	.742751	7.03
.535374	4.63	.717851	7.03	56	.551842	4.52	.743173	7.03
.535652	4.62	.718273	7.05	57	.552113	4.52	.743595	7.02
.535929	4.63	.718696	7.03	58	.552384	4.53	.744016	7.03
.536207	4.62	.719118	7.05	59	.552656	4.52	.744438	7.02
9.536484	4.62	9.719541	7.05	60	9.552927	4.50	9.744859	7.02

	74°					75°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.859956	2.80	10.419618	10.13	0	9.869924	2.75	10.456928	10.60
1	.860124	2.78	.420226	10.15	1	.870089	2.73	.457564	10.62
2	.860291	2.80	.420835	10.17	2	.870253	2.75	.458201	10.63
3	.860459	2.78	.421445	10.15	3	.870418	2.73	.458839	10.62
4	.860626	2.80	.422054	10.17	4	.870582	2.75	.459476	10.65
5	.860794	2.78	.422664	10.18	5	.870747	2.73	.460115	10.65
6	.860961	2.78	.423275	10.18	6	.870911	2.75	.460754	10.65
7	.861128	2.80	.423886	10.20	7	.871076	2.73	.461393	10.67
8	.861296	2.78	.424498	10.20	8	.871240	2.73	.462033	10.67
9	.861463	2.78	.425110	10.20	9	.871404	2.73	.462673	10.68
10	.861630	2.78	.425722	10.22	10	.871568	2.73	.463314	10.70
11	9.861797	2.78	10.426335	10.22	11	9.871732	2.73	10.463956	10.70
12	.861964	2.78	.426948	10.23	12	.871896	2.73	.464598	10.70
13	.862131	2.78	.427562	10.23	13	.872060	2.73	.465240	10.73
14	.862298	2.78	.428176	10.23	14	.872224	2.73	.465883	10.73
15	.862465	2.78	.428790	10.27	15	.872388	2.73	.466527	10.73
16	.862632	2.78	.429406	10.25	16	.872552	2.73	.467171	10.73
17	.862799	2.77	.430021	10.27	17	.872716	2.73	.467815	10.75
18	.862965	2.78	.430637	10.27	18	.872880	2.72	.468460	10.77
19	.863132	2.78	.431253	10.28	19	.873043	2.73	.469106	10.77
20	.863299	2.77	.431870	10.30	20	.873207	2.73	.469752	10.77
21	9.863465	2.78	10.432488	10.28	21	9.873371	2.72	10.470398	10.78
22	.863632	2.78	.433105	10.32	22	.873534	2.73	.471045	10.80
23	.863799	2.77	.433724	10.30	23	.873698	2.72	.471693	10.80
24	.863965	2.77	.434342	10.32	24	.873861	2.73	.472341	10.82
25	.864131	2.78	.434961	10.33	25	.874025	2.72	.472990	10.82
26	.864298	2.77	.435581	10.33	26	.874188	2.72	.473639	10.83
27	.864464	2.77	.436201	10.33	27	.874351	2.73	.474289	10.83
28	.864630	2.78	.436821	10.35	28	.874515	2.72	.474939	10.85
29	.864797	2.77	.437442	10.37	29	.874678	2.72	.475590	10.87
30	.864963	2.77	.438064	10.37	30	.874841	2.72	.476242	10.85
31	9.865129	2.77	10.438686	10.37	31	9.875004	2.72	10.476893	10.88
32	.865295	2.77	.439308	10.38	32	.875167	2.72	.477546	10.88
33	.865461	2.77	.439931	10.38	33	.875330	2.72	.478199	10.88
34	.865627	2.77	.440554	10.40	34	.875493	2.72	.478852	10.90
35	.865793	2.77	.441178	10.40	35	.875656	2.72	.479506	10.92
36	.865959	2.75	.441802	10.42	36	.875819	2.72	.480161	10.92
37	.866124	2.77	.442427	10.42	37	.875982	2.72	.480816	10.93
38	.866290	2.77	.443052	10.43	38	.876145	2.72	.481472	10.93
39	.866456	2.77	.443678	10.43	39	.876308	2.70	.482128	10.95
40	.866622	2.75	.444304	10.45	40	.876470	2.72	.482785	10.95
41	9.866787	2.77	10.444931	10.45	41	9.876633	2.72	10.483442	10.97
42	.866953	2.75	.445558	10.45	42	.876796	2.70	.484100	10.98
43	.867118	2.77	.446185	10.47	43	.876958	2.72	.484759	10.98
44	.867284	2.75	.446813	10.48	44	.877121	2.70	.485418	10.98
45	.867449	2.75	.447442	10.48	45	.877283	2.70	.486077	10.98
46	.867614	2.77	.448071	10.48	46	.877445	2.72	.486738	11.00
47	.867780	2.75	.448700	10.50	47	.877608	2.70	.487398	11.02
48	.867945	2.75	.449330	10.52	48	.877770	2.70	.488059	11.03
49	.868110	2.75	.449961	10.52	49	.877932	2.72	.488721	11.05
50	.868275	2.77	.450592	10.52	50	.878095	2.70	.489384	11.05
51	9.868441	2.75	10.451223	10.53	51	9.878257	2.70	10.490047	11.05
52	.868606	2.75	.451855	10.53	52	.878419	2.70	.490710	11.07
53	.868771	2.75	.452487	10.55	53	.878581	2.70	.491374	11.08
54	.868936	2.73	.453120	10.57	54	.878743	2.70	.492039	11.08
55	.869100	2.75	.453754	10.57	55	.878905	2.70	.492704	11.10
56	.869265	2.75	.454388	10.57	56	.879067	2.70	.493370	11.10
7	.869430	2.75	.455022	10.58	57	.879229	2.68	.494036	11.1
	.869595	2.75	.455657	10.58	58	.879390	2.70	.494703	11.
	.869760	2.73	.456292	10.60	59	.879552	2.70	.495371	11
	9.869924	2.75	10.456928	10.60	60	9.879714	2.70	10.496039	1

	76°					77°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.879714	2.70	10.496039	11.13	0	9.889329	2.65	10.537241	11.77
1	.879876	2.68	.496707	11.17	1	.889488	2.65	.537947	11.78
2	.880037	2.70	.497377	11.17	2	.889647	2.63	.538654	11.80
3	.880199	2.68	.498047	11.17	3	.889805	2.65	.539362	11.82
4	.880360	2.70	.498717	11.18	4	.889964	2.65	.540071	11.82
5	.880522	2.68	.499388	11.20	5	.890123	2.63	.540780	11.83
6	.880683	2.70	.500060	11.20	6	.890281	2.65	.541490	11.83
7	.880845	2.68	.500732	11.22	7	.890440	2.63	.542200	11.85
8	.881006	2.68	.501405	11.22	8	.890598	2.65	.542911	11.87
9	.881167	2.70	.502078	11.23	9	.890757	2.63	.543623	11.88
10	.881329	2.68	.502752	11.23	10	.890915	2.63	.544336	11.88
11	9.881490	2.68	10.503426	11.27	11	9.891073	2.65	10.545049	11.90
12	.881651	2.68	.504102	11.25	12	.891232	2.63	.545763	11.90
13	.881812	2.68	.504777	11.28	13	.891390	2.63	.546477	11.93
14	.881973	2.68	.505454	11.28	14	.891548	2.63	.547193	11.93
15	.882134	2.68	.506131	11.28	15	.891706	2.63	.547909	11.95
16	.882295	2.68	.506808	11.30	16	.891864	2.63	.548626	11.95
17	.882456	2.68	.507486	11.32	17	.892022	2.63	.549343	11.97
18	.882617	2.67	.508165	11.32	18	.892180	2.63	.550061	11.98
19	.882777	2.68	.508844	11.33	19	.892338	2.63	.550780	12.00
20	.882938	2.68	.509524	11.35	20	.892496	2.63	.551500	12.00
21	9.883099	2.68	10.510205	11.35	21	9.892654	2.63	10.552220	12.03
22	.883260	2.67	.510886	11.37	22	.892812	2.62	.552941	12.03
23	.883420	2.68	.511568	11.37	23	.892969	2.63	.553663	12.03
24	.883581	2.67	.512250	11.38	24	.893127	2.63	.554385	12.07
25	.883741	2.68	.512933	11.40	25	.893285	2.62	.555109	12.07
26	.883902	2.67	.513617	11.40	26	.893442	2.63	.555833	12.07
27	.884062	2.68	.514301	11.42	27	.893600	2.63	.556557	12.10
28	.884223	2.67	.514986	11.43	28	.893758	2.62	.557283	12.10
29	.884383	2.67	.515672	11.43	29	.893915	2.62	.558009	12.13
30	.884543	2.67	.516358	11.45	30	.894072	2.63	.558736	12.13
31	9.884703	2.68	10.517045	11.45	31	9.894230	2.62	10.559463	12.15
32	.884864	2.67	.517732	11.47	32	.894387	2.62	.560192	12.15
33	.885024	2.67	.518420	11.48	33	.894544	2.63	.560921	12.17
34	.885184	2.67	.519109	11.48	34	.894702	2.62	.561651	12.17
35	.885344	2.67	.519798	11.50	35	.894859	2.62	.562381	12.20
36	.885504	2.67	.520488	11.52	36	.895016	2.62	.563113	12.20
37	.885664	2.67	.521179	11.50	37	.895173	2.62	.563845	12.20
38	.885824	2.65	.521870	11.53	38	.895330	2.62	.564577	12.23
39	.885983	2.67	.522562	11.53	39	.895487	2.62	.565311	12.23
40	.886143	2.67	.523254	11.55	40	.895644	2.62	.566045	12.27
41	9.886303	2.67	10.523947	11.57	41	9.895801	2.62	10.566781	12.25
42	.886463	2.65	.524641	11.57	42	.895958	2.62	.567516	12.28
43	.886622	2.67	.525335	11.58	43	.896115	2.62	.568253	12.28
44	.886782	2.65	.526030	11.60	44	.896272	2.60	.568990	12.32
45	.886941	2.67	.526726	11.62	45	.896428	2.62	.569729	12.32
46	.887101	2.65	.527423	11.62	46	.896585	2.62	.570468	12.32
47	.887260	2.67	.528120	11.62	47	.896742	2.60	.571207	12.35
48	.887420	2.65	.528817	11.65	48	.896898	2.62	.571948	12.35
49	.887579	2.67	.529516	11.65	49	.897055	2.60	.572689	12.37
50	.887739	2.65	.530215	11.65	50	.897211	2.62	.573431	12.38
51	9.887898	2.65	10.530914	11.67	51	9.897368	2.60	10.574174	12.38
52	.888057	2.65	.531614	11.68	52	.897524	2.60	.574917	12.42
53	.888216	2.65	.532315	11.70	53	.897680	2.62	.575662	12.42
54	.888375	2.65	.533017	11.70	54	.897837	2.60	.576407	12.43
55	.888534	2.65	.533719	11.72	55	.897993	2.60	.577153	12.45
56	.888693	2.65	.534422	11.73	56	.898149	2.60	.577900	12.45
57	.888852	2.65	.535126	11.73	57	.898305	2.60	.578647	12.4
58	.889011	2.65	.535830	11.75	58	.898461	2.62	.579396	12.
59	.889170	2.65	.536535	11.77	59	.898618	2.60	.580145	12
60	9.889329	2.65	10.537241	11.77	60	9.898774	2.60	10.580895	

	78°					79°		
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.
0	9.898774	2.60	10.580895	12.50	0	9.908051	2.55	10.627452
1	.898930	2.60	.581645	12.53	1	.908204	2.55	.628256
2	.899086	2.58	.582397	12.53	2	.908357	2.57	.629060
3	.899241	2.60	.583149	12.57	3	.908511	2.55	.629866
4	.899397	2.60	.583903	12.57	4	.908664	2.55	.630673
5	.899553	2.60	.584657	12.57	5	.908817	2.55	.631480
6	.899709	2.60	.585411	12.60	6	.908970	2.55	.632289
7	.899865	2.58	.586167	12.60	7	.909123	2.55	.633098
8	.900020	2.60	.586923	12.63	8	.909276	2.53	.633909
9	.900176	2.58	.587681	12.63	9	.909428	2.55	.634720
10	.900331	2.60	.588439	12.65	10	.909581	2.55	.635533
11	9.900487	2.58	10.589198	12.65	11	9.909734	2.55	10.636346
12	.900642	2.60	.589957	12.68	12	.909887	2.53	.637161
13	.900798	2.58	.590718	12.68	13	.910039	2.55	.637976
14	.900953	2.58	.591479	12.72	14	.910192	2.55	.638792
15	.901108	2.60	.592242	12.72	15	.910345	2.53	.639610
16	.901264	2.58	.593005	12.73	16	.910497	2.55	.640428
17	.901419	2.58	.593769	12.73	17	.910650	2.53	.641248
18	.901574	2.58	.594533	12.77	18	.910802	2.55	.642068
19	.901729	2.58	.595299	12.78	19	.910955	2.53	.642890
20	.901884	2.60	.596066	12.78	20	.911107	2.53	.643713
21	9.902040	2.58	10.596833	12.80	21	9.911259	2.55	10.644536
22	.902195	2.58	.597601	12.82	22	.911412	2.53	.645361
23	.902350	2 57	.598370	12.83	23	.911564	2.53	.646186
24	.902504	2.58	.599140	12.85	24	.911716	2.53	.647013
25	.902659	2.58	.599911	12.85	25	.911868	2.53	.647841
26	.902814	2.58	.600682	12.88	26	.912020	2.53	.648670
27	.902969	2.58	.601455	12.88	27	.912172	2.53	.649499
28	.903124	2.57	.602228	12.92	28	.912324	2.53	.650330
29	.903278	2.58	.603003	12.92	29	.912476	2.53	.651162
30	.903433	2.58	.603778	12.93	30	.912628	2.53	.651995
31	9.903588	2.57	10.604554	12.95	31	9.912780	2.53	10.652829
32	.903742	2.58	.605331	12.95	32	.912932	2.53	.653664
33	.903897	2.57	.606108	12.98	33	.913084	2.52	.654501
34	.904051	2.58	.606887	13.00	34	.913235	2.53	.655338
35	.904206	2.57	.607667	13.00	35	.913387	2.53	.656176
36	.904360	2.57	.608447	13.02	36	.913539	2.52	.657016
37	.904514	2.57	.609228	13.03	37	.913690	2.53	.657856
38	.904668	2.58	.610010	13.07	38	.913842	2.52	.658698
39	.904823	2.57	.610794	13 07	39	.913993	2.53	.659540
40	.904977	2.57	.611578	13.08	40	.914145	2.52	.660384
41	9.905131	2.57	10.612363	13.08	41	9.914296	2.53	10.661229
42	.905285	2.57	.613148	13.12	42	.914448	2.52	.662075
43	.905439	2.57	.613935	13.13	43	.914599	2.52	.662922
44	.905593	2.57	.614723	13.13	44	.914750	2.53	.663770
45	.905747	2.57	.615511	13.17	45	.914902	2.52	.664619
46	.905901	2.57	.616301	13.17	46	.915053	2.52	.665470
47	.906055	2.57	.617091	13.20	47	.915204	2.52	.666321
48	.906209	2.57	.617883	13 20	48	.915355	2.52	.667174
49	.906363	2.55	.618675	13.22	49	.915506	2.52	.668028
50	.906516	2.57	.619468	13.23	50	.915657	2.52	.668883
51	9.906670	2.57	10.620262	13.25	51	9.915808	2.52	10.669739
52	.906824	2.55	.621057	13.27	52	.915959	2.52	.670596
53	.906977	2.57	.621853	13.28	53	.916110	2.52	.671454
54	.907131	2.55	.622650	13.30	54	.916261	2.52	.672314
55	.907284	2.57	.623448	13.32	55	.916412	2.50	.673174
56	.907438	2.55	.624247	13.33	56	.916562	2.52	.67403
	.907591	2.55	.625047	13.35	57	.916713	2.52	.67489
	.907744	2.57	.625848	13.37	58	.916864	2.50	.6757
	.907898	2.55	.626650	13.37	59	.917014	2.52	.676
	9.908051	2.55	10.627452	13.40	60	9.917165	2.52	10.67

80°					81°			
Vers.	D. 1".	Ex. sec.	D. 1".	′	Vers.	D. 1".	Ex. sec.	D. 1".
9.917165	2.52	10.677495	14.45	0	9.926119	2.47	10.731786	15.78
.917316	2.50	.678362	14.48	1	.926267	2.47	.732733	15.78
.917466	2.50	.679231	14.50	2	.926415	2.45	.733680	15.83
.917616	2.52	.680101	14.52	3	.926562	2.47	.734630	15.83
.917767	2.50	.680972	14.55	4	.926710	2.47	.735580	15.87
.917917	2.52	.681845	14.55	5	.926858	2.47	.736532	15.90
.918068	2.50	.682718	14.58	6	.927006	2.45	.737486	15.92
.918218	2.50	.683593	14.60	7	.927153	2.47	.738441	15.95
.918368	2.50	.684469	14.62	8	.927301	2.45	.739398	15.97
.918518	2.50	.685346	14.63	9	.927448	2.47	.740356	16.00
.918668	2.50	.686224	14.67	10	.927596	2.45	.741316	16.02
9.918818	2.50	10.687104	14.68	11	9.927743	2.47	10.742277	16.03
.918968	2.50	.687985	14.70	12	.927891	2.45	.743239	16.08
.919118	2.50	.688867	14.72	13	.928038	2.45	.744204	16.08
.919268	2.50	.689750	14.73	14	.928185	2.47	.745169	16.13
.919418	2.50	.690634	14.77	15	.928333	2.45	.746137	16.13
.919568	2.50	.691520	14.78	16	.928480	2.45	.747105	16.18
.919718	2.50	.692407	14.80	17	.928627	2.45	.748076	16.20
.919868	2.50	.693295	14.83	18	.928774	2.45	.749048	16.22
.920018	2.48	.694185	14.83	19	.928921	2.45	.750021	16.25
.920167	2.50	.695075	14.87	20	.929068	2.45	.750096	16.28
9.920317	2.48	10.695967	14.90	21	9.929215	2.45	10.751973	16.30
.920466	2.50	.696861	14.90	22	.929362	2.45	.752951	16.33
.920616	2.50	.697755	14.93	23	.929509	2.45	.753931	16.35
.920766	2.48	.698651	14.95	24	.929656	2.45	.754912	16.38
.920915	2.48	.699548	14.97	25	.929803	2.45	.755895	16.42
.921064	2.50	.700446	15.00	26	.929950	2.45	.756880	16.43
.921214	2.48	.701346	15.02	27	.930097	2.43	.757866	16.47
.921363	2.48	.702247	15.03	28	.930243	2.45	.758854	16.50
.921512	2.50	.703149	15.05	29	.930390	2.45	.759844	16.52
.921662	2.48	.704052	15.08	30	.930537	2.43	.760835	16.53
9.921811	2.48	10.704957	15.10	31	9.930683	2.45	10.761827	16.58
.921960	2.48	.705863	15.13	32	.930830	2.43	.762822	16.60
.922109	2.48	.706771	15.15	33	.930976	2.45	.763818	16.62
.922258	2.48	.707680	15.17	34	.931123	2.43	.764815	16.67
.922407	2.48	.708590	15.18	35	.931269	2.45	.765815	16.68
.922556	2.48	.709501	15.22	36	.931416	2.43	.766816	16.72
.922705	2.48	.710414	15.23	37	.931562	2.43	.767819	16.73
.922854	2.48	.711328	15.25	38	.931708	2.45	.768823	16.77
.923003	2.48	.712243	15.28	39	.931855	2.43	.769829	16.80
.923152	2.48	.713160	15.30	40	.932001	2.43	.770837	16.82
9.923301	2.47	10.714078	15.33	41	9.932147	2.43	10.771846	16.87
.923449	2.48	.714998	15.35	42	.932293	2.43	.772858	16.87
.923598	2.48	.715919	15.37	43	.932439	2.43	.773870	16.92
.923747	2.47	.716841	15.38	44	.932585	2.43	.774885	16.95
.923895	2.48	.717764	15.42	45	.932731	2.43	.775902	16.97
.924044	2.47	.718689	15.45	46	.932877	2.43	.776920	17.00
.924192	2.48	.719616	15.45	47	.933023	2.43	.777940	17.02
.924341	2.47	.720543	15.48	48	.933169	2.43	.778961	17.07
.924489	2.47	.721472	15.52	49	.933315	2.42	.779985	17.08
.924637	2.48	.722403	15.53	50	.933460	2.43	.781010	17.12
9.924786	2.47	10.723335	15.55	51	9.933606	2.43	10.782037	17.13
.924934	2.47	.724268	15.58	52	.933752	2.42	.783065	17.18
.925082	2.48	.725203	15.60	53	.933897	2.43	.784096	17.20
.925231	2.47	.726139	15.63	54	.934043	2.43	.785128	17.23
.925379	2.47	.727077	15.65	55	.934189	2.42	.786162	17.27
.925527	2.47	.728016	15.67	56	.934334	2.43	.787198	17.30
.925675	2.47	.728956	15.70	57	.934480	2.42	.788236	[illegible]
.925823	2.47	.729898	15.73	58	.934625	2.42	.789276	[illegible]
.925971	2.47	.730842	15.73	59	.934770	2.43	.790317	
9.926119	2.47	10.731786	15.78	60	9.934916	2.42	10.79136	

	82°					83°			
′	Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.934916	2.42	10.791361	17.42	0	9.943559	2.38	10.857665	19.55
1	.935061	2.42	.792406	17.45	1	.943702	2.38	.858838	19.58
2	.935206	2.43	.793453	17.48	2	.943845	2.37	.860018	19.63
3	.935352	2.42	.794502	17.50	3	.943987	2.38	.861191	19.67
4	.935497	2.42	.795552	17.55	4	.944130	2.38	.862371	19.72
5	.935642	2.42	.796605	17.58	5	.944273	2.37	.863554	19.75
6	.935787	2.42	.797660	17.60	6	.944415	2.38	.864739	19.80
7	.935932	2.42	.798716	17.63	7	.944558	2.37	.865927	19.83
8	.936077	2.42	.799774	17.68	8	.944700	2.38	.867117	19.88
9	.936222	2.42	.800835	17.70	9	.944843	2.37	.868310	19.92
10	.936367	2.42	.801897	17.73	10	.944985	2.37	.869505	19.97
11	9.936512	2.42	10.802961	17.77	11	9.945127	2.38	10.870703	20.00
12	.936657	2.40	.804027	17.80	12	.945270	2.37	.871908	20.05
13	.936801	2.42	.805095	17.83	13	.945412	2.37	.873106	20.10
14	.936946	2.42	.806165	17.87	14	.945554	2.37	.874312	20.13
15	.937091	2.42	.807237	17.90	15	.945696	2.37	.875520	20.18
16	.937236	2.40	.808311	17.93	16	.945838	2.38	.876731	20.23
17	.937380	2.42	.809387	17.97	17	.945981	2.37	.877945	20.27
18	.937525	2.40	.810465	18.00	18	.946123	2.37	.879161	20.30
19	.937669	2.42	.811545	18.03	19	.946265	2.37	.880379	20.37
20	.937814	2.40	.812627	18.07	20	.946407	2.37	.881601	20.40
21	9.937958	2.42	10.813711	18.10	21	9.946549	2.35	10.882825	20.45
22	.938103	2.40	.814797	18.13	22	.946690	2.37	.884052	20.48
23	.938247	2.40	.815885	18.17	23	.946832	2.37	.885281	20.55
24	.938391	2.42	.816975	18.20	24	.946974	2.37	.886514	20.58
25	.938536	2.40	.818067	18.23	25	.947116	2.37	.887749	20.62
26	.938680	2.40	.819161	18.27	26	.947258	2.35	.888986	20.68
27	.938824	2.40	.820257	18.32	27	.947399	2.37	.890227	20.72
28	.938968	2.40	.821356	18.33	28	.947541	2.37	.891470	20.77
29	.939112	2.42	.822456	18.38	29	.947683	2.35	.892716	20.82
30	.939257	2.40	.823559	18.42	30	.947824	2.37	.893965	20.87
31	9.939401	2.40	10.824664	18.43	31	9.947966	2.35	10.895217	20.92
32	.939545	2.38	.825770	18.48	32	.948107	2.37	.896472	20.95
33	.939688	2.40	.826879	18.52	33	.948249	2.35	.897729	21.00
34	.939832	2.40	.827990	18.57	34	.948390	2.35	.898989	21.07
35	.939976	2.40	.820104	18.58	35	.948531	2.37	.900253	21.10
36	.940120	2.40	.830219	18.63	36	.948673	2.35	.901519	21.15
37	.940264	2.40	.831337	18.65	37	.948814	2.35	.902788	21.20
38	.940408	2.38	.832456	18.70	38	.948955	2.35	.904060	21.25
39	.940551	2.40	.833578	18.75	39	.949096	2.35	.905335	21.30
40	.940695	2.40	.834703	18.77	40	.949237	2.37	.906613	21.33
41	9.940839	2.38	10.835829	18.80	41	9.949379	2.35	10.907893	21.40
42	.940982	2.40	.836957	18.85	42	.949520	2.35	.909177	21.45
43	.941126	2.38	.838088	18.88	43	.949661	2.35	.910464	21.50
44	.941269	2.40	.839221	18.93	44	.949802	2.35	.911754	21.55
45	.941413	2.38	.840357	18.95	45	.949943	2.33	.913047	21.60
46	.941556	2.38	.841494	19.00	46	.950083	2.35	.914343	21.65
47	.941699	2.40	.842634	19.03	47	.950224	2.35	.915642	21.70
48	.941843	2.38	.843776	19.08	48	.950365	2.35	.916944	21.75
49	.941986	2.38	.844921	19.12	49	.950506	2.35	.918249	21.82
50	.942129	2.38	.846068	19.15	50	.950647	2.33	.919558	21.85
51	9.942272	2.38	10.847217	19.18	51	9.950787	2.35	10.920869	21.92
52	.942415	2.40	.848368	19.23	52	.950928	2.35	.922184	21.97
53	.942559	2.38	.849522	19.27	53	.951069	2.33	.923502	22.03
54	.942702	2.38	.850678	19.30	54	.951209	2.35	.924823	22.07
55	.942845	2.38	.851836	19.35	55	.951350	2.33	.926147	22.13
56	.942988	2.38	.852997	19.40	56	.951490	2.35	.927475	22.17
57	.943131	2.37	.854161	19.42	57	.951631	2.33	.928805	22.23
58	.943273	2.38	.855326	19.47	58	.951771	2.33	.930139	22.30
59	.943416	2.38	.856494	19.52	59	.951911	2.35	.931477	22.33
	9.943559	2.38	10.857665	19.55	60	9.952052	2.33	10.932817	22.40

84°					85°			
Vers.	D. 1″.	Ex. sec.	D. 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
9.952052	2.33	10.932817	22.40	0	9.960397	2.30	11.020101	26.40
.952192	2.33	.934161	22.45	1	.960535	2.28	.021685	26.48
.952332	2.35	.935508	22.52	2	.960672	2.30	.023274	26.57
.952473	2.33	.936859	22.57	3	.960810	2.30	.024868	26.65
.952613	2.33	.938213	22.62	4	.960948	2.30	.026467	26.73
.952753	2.33	.939570	22.68	5	.961086	2.28	.028071	26.80
.952893	2.33	.940931	22.75	6	.961223	2.30	.029679	26.90
.953033	2.33	.942296	22.78	7	.961361	2.28	.031293	26.98
.953173	2.33	.943668	22.85	8	.961498	2.30	.032912	27.07
.953313	2.33	.945034	22.92	9	.961636	2.28	.034536	27.13
.953453	2.33	.946409	22.97	10	.961773	2.30	.036164	27.23
9.953593	2.32	10.947787	23.03	11	9.961911	2.28	11.037798	27.33
.953732	2.33	.949169	23.08	12	.962048	2.30	.039438	27.40
.953872	2.33	.950554	23.15	13	.962186	2.28	.041082	27.50
.954012	2.33	.951943	23.22	14	.962323	2.28	.042732	27.58
.954152	2.32	.953336	23.27	15	.962460	2.28	.044387	27.67
.954291	2.33	.954732	23.33	16	.962597	2.30	.046047	27.77
.954431	2.33	.956132	23.38	17	.962735	2.28	.047713	27.85
.954571	2.32	.957535	23.45	18	.962872	2.28	.049384	27.93
.954710	2.33	.958942	23.52	19	.963009	2.28	.051060	28.03
.954850	2.32	.960353	23.57	20	.963146	2.28	.052742	28.13
9.954989	2.33	10.961767	23.65	21	9.963283	2.28	11.054430	28.22
.955129	2.32	.963186	23.70	22	.963420	2.28	.056123	28.30
.955268	2.32	.964608	23.77	23	.963557	2.28	.057821	28.40
.955407	2.33	.966034	23.82	24	.963694	2.28	.059525	28.50
.955547	2.32	.967463	23.90	25	.963831	2.28	.061235	28.60
.955686	2.32	.968897	23.95	26	.963968	2.27	.062951	28.68
.955825	2.32	.970334	24.02	27	.964104	2.28	.064672	28.78
.955964	2.32	.971775	24.10	28	.964241	2.28	.066399	28.88
.956103	2.33	.973221	24.15	29	.964378	2.28	.068132	28.98
.956243	2.32	.974670	24.22	30	.964515	2.27	.069871	29.08
9.956382	2.32	10.976123	24.28	31	9.964651	2.28	11.071616	29.18
.956521	2.32	.977580	24.35	32	.964788	2.27	.073367	29.28
.956660	2.32	.979041	24.42	33	.964924	2.28	.075124	29.38
.956799	2.30	.980506	24.48	34	.965061	2.27	.076887	29.48
.956937	2.32	.981975	24.55	35	.965197	2.28	.078656	29.58
.957076	2.32	.983448	24.63	36	.965334	2.27	.080431	29.68
.957215	2.32	.984926	24.68	37	.965460	2.28	.082212	29.80
.957354	2.32	.986407	24.77	38	.965607	2.27	.084000	29.90
.957493	2.30	.987893	24.83	39	.965743	2.27	.085794	30.00
.957631	2.32	.989383	24.90	40	.965879	2.28	.087594	30.12
9.957770	2.32	10.990877	24.97	41	9.966016	2.27	11.089401	30.22
.957909	2.30	.992375	25.03	42	.966152	2.27	.091214	30.32
.958047	2.32	.993877	25.12	43	.966288	2.27	.093033	30.43
.958186	2.30	.995384	25.18	44	.966424	2.27	.094859	30.55
.958324	2.32	.996895	25.27	45	.966560	2.27	.096692	30.67
.958463	2.30	.998411	25.33	46	.966696	2.27	.098532	30.77
.958601	2.30	.999931	25.40	47	.966832	2.27	.100378	30.87
.958739	2.32	11.001455	25.48	48	.966968	2.27	.102230	31.00
.958878	2.30	.002984	25.55	49	.967104	2.27	.104090	31.12
.959016	2.30	.004517	25.63	50	.967240	2.27	.105957	31.22
9.959154	2.30	11.006055	25.70	51	9.967376	2.27	11.107830	31.35
.959292	2.32	.007597	25.78	52	.967512	2.25	.109711	31.45
.959431	2.30	.009144	25.85	53	.967647	2.27	.111598	31.58
.959569	2.30	.010695	25.93	54	.967783	2.27	.113493	31.68
.959707	2.30	.012251	26.00	55	.967919	2.25	.115394	31.82
.959845	2.30	.013811	26.10	56	.968054	2.27	.117303	31.93
.959983	2.30	.015377	26.17	57	.968190	2.27	.119219	32.07
.960121	2.30	.016947	26.23	58	.968326	2.25	.121148	32.18
.960259	2.30	.018521	26.33	59	.968461	2.27	.123074	32.30
9.960397	*2.30*	*11.020101*	26.40	60	9.968597	2.25	11.125012	38

86°					87°				
′	Vers.	D. 1″.	Ex. sec.	D 1″.	′	Vers.	D. 1″.	Ex. sec.	D. 1″.
0	9.968597	2.25	11.125012	32.43	0	9.976654	2.23	11.257854	42.52
1	.968732	2.27	.126958	32.55	1	.976788	2.22	.260405	42.73
2	.968868	2.25	.128911	32.70	2	.976921	2.22	.262969	42.95
3	.969003	2.25	.130873	32.80	3	.977054	2.22	.265546	43.20
4	.969138	2.27	.132841	32.95	4	.977187	2.22	.268138	43.42
5	.969274	2.25	.134818	33.07	5	.977320	2.20	.270743	43.67
6	.969409	2.25	.136802	33.22	6	.977452	2.22	.273363	43.88
7	.969544	2.25	.138795	33.33	7	.977585	2.22	.275996	44.15
8	.969679	2.25	.140795	33.47	8	.977718	2.22	.278645	44.38
9	.969814	2.25	.142803	33.62	9	.977851	2.22	.281308	44.63
10	.969949	2.25	.144820	33.73	10	.977984	2.20	.283986	44.88
11	9.970084	2.25	11.146844	33.88	11	9.978116	2.22	11.286679	45.13
12	.970219	2.25	.148877	34.02	12	.978249	2.22	.289387	45.38
13	.970354	2.25	.150918	34.17	13	.978382	2.20	.292110	45.65
14	.970489	2.25	.152968	34.30	14	.978514	2.22	.294849	45.92
15	.970624	2.25	.155026	34.43	15	.978617	2.20	.297604	46.17
16	.970759	2.25	.157092	34.60	16	.978779	2.22	.300374	46.45
17	.970894	2.25	.159168	34.73	17	.978912	2.20	.303161	46.72
18	.971029	2.25	.161252	34.87	18	.979044	2.22	.305964	47.00
19	.971164	2.23	.163344	35.03	19	.979177	2.20	.308784	47.27
20	.971298	2.25	.165446	35.17	20	.979309	2.22	.311620	47.55
21	9.971433	2.25	11.167556	35.33	21	9.979442	2.20	11.314473	47.83
22	.971568	2.23	.169676	35.48	22	.979574	2.20	.317343	48.13
23	.971702	2.25	.171805	35.63	23	.979706	2.20	.320231	48.43
24	.971837	2.23	.173943	35.78	24	.979838	2.20	.323137	48.72
25	.971971	2.25	.176090	35.93	25	.979970	2.22	.326060	49.02
26	.972106	2.23	.178246	36.10	26	.980103	2.20	.329001	49.33
27	.972240	2.23	.180412	36.27	27	.980235	2.20	.331961	49.63
28	.972374	2.25	.182588	36.42	28	.980367	2.20	.334939	49.93
29	.972509	2.23	.184773	36.58	29	.980499	2.20	.337935	50.27
30	.972643	2.23	.186968	36.75	30	.980631	2.20	.340951	50.58
31	9.972777	2.25	11.189173	36.90	31	9.980763	2.20	11.343986	50.92
32	.972912	2.23	.191387	37.08	32	.980895	2.18	.347041	51.23
33	.973046	2.23	.193612	37.25	33	.981026	2.20	.350115	51.58
34	.973180	2.23	.195847	37.42	34	.981158	2.20	.353210	51.92
35	.973314	2.23	.198092	37.58	35	.981290	2.20	.356325	52.25
36	.973448	2.23	.200347	37.77	36	.981422	2.20	.359460	52.62
37	.973582	2.23	.202613	37.93	37	.981554	2.18	.362617	52.95
38	.973716	2.23	.204889	38.12	38	.981685	2.20	.365794	53.32
39	.973850	2.23	.207176	38.28	39	.981817	2.20	.368993	53.68
40	.973984	2.23	.209473	38.47	40	.981949	2.18	.372214	54.07
41	9.974118	2.23	11.211781	38.67	41	9.982080	2.20	11.375458	54.42
42	.974252	2.23	.214101	38.83	42	.982212	2.18	.378723	54.80
43	.974386	2.22	.216431	39.03	43	.982343	2.20	.382011	55.20
44	.974519	2.23	.218773	39.20	44	.982475	2.18	.385323	55.58
45	.974653	2.23	.221125	39.42	45	.982606	2.18	.388658	55.97
46	.974787	2.22	.223490	39.58	46	.982737	2.20	.392016	56.38
47	.974920	2.23	.225865	39.80	47	.982869	2.18	.395399	56.80
48	.975054	2.23	.228253	39.98	48	.983000	2.18	.398807	57.20
49	.975188	2.22	.230652	40.18	49	.983131	2.18	.402239	57.62
50	.975321	2.23	.233063	40.38	50	.983262	2.20	.405696	58.07
51	9.975455	2.22	11.235486	40.58	51	9.983394	2.18	11.409180	58.48
52	.975588	2.23	.237921	40.78	52	.983525	2.18	.412689	58.93
53	.975722	2.22	.240368	41.00	53	.983656	2.18	.416225	59.38
54	.975855	2.22	.242828	41.20	54	.983787	2.18	.419788	59.83
55	.975988	2.23	.245300	41.42	55	.983918	2.18	.423378	60.28
56	.976122	2.22	.247785	41.63	56	.984049	2.18	.426995	60.77
57	.976255	2.22	.250283	41.83	57	.984180	2.18	.430641	61.25
	.976388	2.22	.252793	42.07	58	.984311	2.18	.434316	61.73
	.976521	2.22	.255317	42.28	59	.984442	2.18	.438020	62.22
	9.976654	2.23	11.257854	42.52	60	9.984573	2.17	11.441753	62.

64°					65°			
ers.	D. 1″.	Ex. sec.	D 1″.	′	Vers.	D. 1″.	Ex. sec.	D.1″.
49440	3.38	10.107607	7.70	0	9.761463	3.30	10.135515	7.82
49652	3.37	.108069	7.68	1	.761661	3.32	.135984	7.83
49854	3.37	.108530	7.70	2	.761860	3.30	.136454	7.82
50056	3.37	.108992	7.68	3	.762058	3.30	.136923	7.83
50258	3.35	.109453	7.70	4	.762256	3.30	.137393	7.83
50459	3.37	.109915	7.70	5	.762454	3.30	.137863	7.83
50661	3.37	.110377	7.70	6	.762652	3.30	.138333	7.83
50863	3.37	.110839	7.70	7	.762850	3.28	.138803	7.83
51065	3.35	.111301	7.70	8	.763047	3.30	.139273	7.85
51266	3.37	.111763	7.72	9	.763245	3.30	.139744	7.83
51468	3.35	.112226	7.70	10	.763443	3.30	.140214	7.85
51669	3.37	10.112688	7.72	11	9.763641	3.28	10.140685	7.85
51871	3.35	.113151	7.72	12	.763838	3.30	.141156	7.85
52072	3.35	.113614	7.72	13	.764036	3.28	.141627	7.85
52273	3.37	.114077	7.72	14	.764233	3.28	.142098	7.85
52475	3.35	.114540	7.72	15	.764430	3.30	.142569	7.87
52676	3.35	.115003	7.72	16	.764628	3.28	.143041	7.85
52877	3.35	.115466	7.72	17	.764825	3.28	.143512	7.87
53078	3.35	.115929	7.73	18	.765022	3.28	.143984	7.87
53279	3.35	.116393	7.73	19	.765219	3.28	.144456	7.87
53480	3.35	.116857	7.73	20	.765416	3.28	.144928	7.87
53681	3.33	10.117321	7.73	21	9.765613	3.28	10.145400	7.87
53881	3.35	.117785	7.73	22	.765810	3.28	.145872	7.88
54082	3.35	.118249	7.73	23	.766007	3.28	.146345	7.88
54283	3.33	.118713	7.73	24	.766204	3.28	.146818	7.87
54483	3.35	.119177	7.75	25	.766401	3.27	.147290	7.88
54684	3.33	.119642	7.73	26	.766597	3.28	.147763	7.88
54884	3.35	.120106	7.75	27	.766794	3.28	.148236	7.90
55085	3.33	.120571	7.75	28	.766991	3.27	.148710	7.88
55285	3.33	.121036	7.75	29	.767187	3.28	.149183	7.90
55485	3.33	.121501	7.75	30	.767384	3.27	.149657	7.88
55685	3.35	10.121966	7.75	31	9.767580	3.27	10.150130	7.90
55886	3.33	.122431	7.77	32	.767776	3.27	.150604	7.90
56086	3.33	.122897	7.75	33	.767972	3.28	.151078	7.90
56286	3.33	.123362	7.77	34	.768169	3.27	.151552	7.92
56486	3.32	.123828	7.77	35	.768365	3.27	.152027	7.90
56685	3.33	.124294	7.77	36	.768561	3.27	.152501	7.92
56885	3.33	.124760	7.77	37	.768757	3.27	.152976	7.90
57085	3.33	.125226	7.77	38	.768953	3.27	.153450	7.92
57285	3.32	.125692	7.77	39	.769149	3.25	.153925	7.92
57484	3.33	.126158	7.78	40	.769344	3.27	.154400	7.93
57684	3.32	10.126625	7.78	41	9.769540	3.27	10.154876	7.92
57883	3.33	.127092	7.77	42	.769736	3.25	.155351	7.92
8083	3.32	.127558	7.78	43	.769931	3.27	.155826	7.93
8282	3.32	.128025	7.78	44	.770127	3.27	.156302	7.93
8481	3.33	.128492	7.80	45	.770323	3.25	.156778	7.93
8681	3.32	.128960	7.78	46	.770518	3.25	.157254	7.93
8880	3.32	.129427	7.78	47	.770713	3.27	.157730	7.93
9079	3.32	.129894	7.80	48	.770909	3.25	.158206	7.95
9278	3.32	.130362	7.80	49	.771104	3.25	.158683	7.93
477	3.32	.130830	7.80	50	.771299	3.25	.159159	7.95
676	3.32	10.131298	7.80	51	9.771494	3.25	10.159636	7.95
875	3.30	.131766	7.80	52	.771689	3.25	.160113	7.95
73	3.32	132234	7.80	53	.771884	3.25	.160590	7.95
72	3.32	.132702	7.80	54	.772079	3.25	.161067	7.97
71	3.30	.133170	7.82	55	.772274	3.25	.161545	7.95
69	3.32	.133639	7.82	56	.772469	3.25	.162022	7.97
68	3.30	.134108	7.82	57	.772664	3.23	.162500	7.97
66	3.32	.134577	7.82	58	.772858	3.25	.162978	7.97
65	3.30	.135046	7.82	59	.773053	3.25	.163456	7.97
63	*3.30*	*10.135515*	7.82	60	9.773248	3.23	10.163934	7.98

′	0°		1°		2°		3°		4°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.00000	One.	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.00029	One.	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.00058	One.	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.00087	One.	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.00116	One.	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.00145	One.	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.00175	One.	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.00204	One.	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.00233	One.	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.00262	One.	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.00291	One.	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.00320	.99999	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.00349	.99999	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.00378	.99999	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.00407	.99999	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.00436	.99999	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.00465	.99999	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.00495	.99999	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.00524	.99999	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.00553	.99998	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.00582	.99998	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.00611	.99998	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.00640	.99998	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.00669	.99998	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.00698	.99998	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.00727	.99997	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.00756	.99997	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.00785	.99997	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.00814	.99997	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.00844	.99996	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.00873	.99996	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.00902	.99996	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.00931	.99996	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.00960	.99995	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.00989	.99995	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.01018	.99995	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.01047	.99995	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.01076	.99994	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.01105	.99994	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.01134	.99994	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.01164	.99993	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.01193	.99993	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.01222	.99993	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.01251	.99992	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.01280	.99992	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.01309	.99991	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.01338	.99991	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.01367	.99991	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.01396	.99990	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.01425	.99990	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.01454	.99989	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.01483	.99989	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.01513	.99989	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.01542	.99988	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.01571	.99988	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.01600	.99987	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.01629	.99987	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.01658	.99986	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.01687	.99986	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.01716	.99985	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	89°		88°		87°		86°		85°		

′	5°		6°		7°		8°		9°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	.15672	.98764	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	.15701	.98760	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	.15730	.98755	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	.15758	.98751	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	.15787	.98746	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	.15816	.98741	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	.15845	.98737	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	.15873	.98732	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	.15902	.98728	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	.15931	.98723	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	.15959	.98718	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	.15988	.98714	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	.16017	.98709	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	.16046	.98704	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	.16074	.98700	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	.16103	.98695	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	.16132	.98690	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	.16160	.98686	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	.16189	.98681	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	.16218	.98676	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	.16246	.98671	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	.16275	.98667	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	.16304	.98662	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	.16333	.98657	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	.16361	.98652	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	.16390	.98648	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	.16419	.98643	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	.16447	.98638	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	.16476	.98633	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	.16505	.98629	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	.16533	.98624	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	.16562	.98619	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	.16591	.98614	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	.16620	.98609	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	.16648	.98604	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	.16677	.98600	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	.16706	.98595	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	.16734	.98590	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	.16763	.98585	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	.16792	.98580	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	.16820	.98575	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	.16849	.98570	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	.16878	.98565	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	.16906	.98561	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	.16935	.98556	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	.16964	.98551	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	.16992	.98546	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	.17021	.98541	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	.17050	.98536	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	.17078	.98531	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	.17107	.98526	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	.17136	.98521	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	.17164	.98516	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	.17193	.98511	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	.17222	.98506	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	.17250	.98501	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	.17279	.98496	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	.17308	.98491	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	.17336	.98486	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	.17365	.98481	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	84°		83°		82°		81°		80°		

′	10°		11°		12°		13°		14°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	60
1	.17393	.98476	.19109	.98157	.20820	.97809	.22523	.97430	.24220	.97023	59
2	.17422	.98471	.19138	.98152	.20848	.97803	.22552	.97424	.24249	.97015	58
3	.17451	.98466	.19167	.98146	.20877	.97797	.22580	.97417	.24277	.97008	57
4	.17479	.98461	.19195	.98140	.20905	.97791	.22608	.97411	.24305	.97001	56
5	.17508	.98455	.19224	.98135	.20933	.97784	.22637	.97404	.24333	.96994	55
6	.17537	.98450	.19252	.98129	.20962	.97778	.22665	.97398	.24362	.96987	54
7	.17565	.98445	.19281	.98124	.20990	.97772	.22693	.97391	.24390	.96980	53
8	.17594	.98440	.19309	.98118	.21019	.97766	.22722	.97384	.24418	.96973	52
9	.17623	.98435	.19338	.98112	.21047	.97760	.22750	.97378	.24446	.96966	51
10	.17651	.98430	.19366	.98107	.21076	.97754	.22778	.97371	.24474	.96959	50
11	.17680	.98425	.19395	.98101	.21104	.97748	.22807	.97365	.24503	.96952	49
12	.17708	.98420	.19423	.98096	.21132	.97742	.22835	.97358	.24531	.96945	48
13	.17737	.98414	.19452	.98090	.21161	.97735	.22863	.97351	.24559	.96937	47
14	.17766	.98409	.19481	.98084	.21189	.97729	.22892	.97345	.24587	.96930	46
15	.17794	.98404	.19509	.98079	.21218	.97723	.22920	.97338	.24615	.96923	45
16	.17823	.98399	.19538	.98073	.21246	.97717	.22948	.97331	.24644	.96916	44
17	.17852	.98394	.19566	.98067	.21275	.97711	.22977	.97325	.24672	.96909	43
18	.17880	.98389	.19595	.98061	.21303	.97705	.23005	.97318	.24700	.96902	42
19	.17909	.98383	.19623	.98056	.21331	.97698	.23033	.97311	.24728	.96894	41
20	.17937	.98378	.19652	.98050	.21360	.97692	.23062	.97304	.24756	.96887	40
21	.17966	.98373	.19680	.98044	.21388	.97686	.23090	.97298	.24784	.96880	39
22	.17995	.98368	.19709	.98039	.21417	.97680	.23118	.97291	.24813	.96873	38
23	.18023	.98362	.19737	.98033	.21445	.97673	.23146	.97284	.24841	.96866	37
24	.18052	.98857	.19766	.98027	.21474	.97667	.23175	.97278	.24869	.96858	36
25	.18081	.98352	.19794	.98021	.21502	.97661	.23203	.97271	.24897	.96851	35
26	.18109	.98347	.19823	.98016	.21530	.97655	.23231	.97264	.24925	.96844	34
27	.18138	.98341	.19851	.98010	.21559	.97648	.23260	.97257	.24954	.96837	33
28	.18166	.98336	.19880	.98004	.21587	.97642	.23288	.97251	.24982	.96829	32
29	.18195	.98331	.19908	.97998	.21616	.97636	.23316	.97244	.25010	.96822	31
30	.18224	.98325	.19937	.97992	.21644	.97630	.23345	.97237	.25038	.96815	30
31	.18252	.98320	.19965	.97987	.21672	.97623	.23373	.97230	.25066	.96807	29
32	.18281	.98315	.19994	.97981	.21701	.97617	.23401	.97223	.25094	.96800	28
33	.18309	.98310	.20022	.97975	.21729	.97611	.23429	.97217	.25122	.96793	27
34	.18338	.98304	.20051	.97969	.21758	.97604	.23458	.97210	.25151	.96786	26
35	.18367	.98299	.20079	.97963	.21786	.97598	.23486	.97203	.25179	.96778	25
36	.18395	.98294	.20108	.97958	.21814	.97592	.23514	.97196	.25207	.96771	24
37	.18424	.98288	.20136	.97952	.21843	.97585	.23542	.97189	.25235	.96764	23
38	.18452	.98283	.20165	.97946	.21871	.97579	.23571	.97182	.25263	.96756	22
39	.18481	.98277	.20193	.97940	.21899	.97573	.23599	.97176	.25291	.96749	21
40	.18509	.98272	.20222	.97934	.21928	.97566	.23627	.97169	.25320	.96742	20
41	.18538	.98267	.20250	.97928	.21956	.97560	.23656	.97162	.25348	.96734	19
42	.18567	.98261	.20279	.97922	.21985	.97553	.23684	.97155	.25376	.96727	18
43	.18595	.98256	.20307	.97916	.22013	.97547	.23712	.97148	.25404	.96719	17
44	.18624	.98250	.20336	.97910	.22041	.97541	.23740	.97141	.25432	.96712	16
45	.18652	.98245	.20364	.97905	.22070	.97534	.23769	.97134	.25460	.96705	15
46	.18681	.98240	.20393	.97899	.22098	.97528	.23797	.97127	.25488	.96697	14
47	.18710	.98234	.20421	.97893	.22126	.97521	.23825	.97120	.25516	.96690	13
48	.18738	.98229	.20450	.97887	.22155	.97515	.23853	.97113	.25545	.96682	12
49	.18767	.98223	.20478	.97881	.22183	.97508	.23882	.97106	.25573	.96675	11
50	.18795	.98218	.20507	.97875	.22212	.97502	.23910	.97100	.25601	.96667	10
51	.18824	.98212	.20535	.97869	.22240	.97496	.23938	.97093	.25629	.96660	9
52	.18852	.98207	.20563	.97863	.22268	.97489	.23966	.97086	.25657	.96653	8
53	.18881	.98201	.20592	.97857	.22297	.97483	.23995	.97079	.25685	.96645	7
54	.18910	.98196	.20620	.97851	.22325	.97476	.24023	.97072	.25713	.96638	6
55	.18938	.98190	.20649	.97845	.22353	.97470	.24051	.97065	.25741	.96630	5
56	.18967	.98185	.20677	.97839	.22382	.97463	.24079	.97058	.25769	.96623	4
57	.18995	.98179	.20706	.97833	.22410	.97457	.24108	.97051	.25798	.96615	3
58	.19024	.98174	.20734	.97827	.22438	.97450	.24136	.97044	.25826	.96608	2
59	.19052	.98168	.20763	.97821	.22467	.97444	.24164	.97037	.25854	.96600	1
60	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	.25882	.96593	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	79°		78°		77°		76°		75°		

′	15°		16°		17°		18°		19°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.25882	.96593	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	60
1	.25910	.96585	.27592	.96118	.29265	.95622	.30929	.95097	.32584	.94542	59
2	.25938	.96578	.27620	.96110	.29293	.95613	.30957	.95088	.32612	.94533	58
3	.25966	.96570	.27648	.96102	.29321	.95605	.30985	.95079	.32639	.94523	57
4	.25994	.96562	.27676	.96094	.29348	.95596	.31012	.95070	.32667	.94514	56
5	.26022	.96555	.27704	.96086	.29376	.95588	.31040	.95061	.32694	.94504	55
6	.26050	.96547	.27731	.96078	.29404	.95579	.31068	.95052	.32722	.94495	54
7	.26079	.96540	.27759	.96070	.29432	.95571	.31095	.95043	.32749	.94485	53
8	.26107	.96532	.27787	.96062	.29460	.95562	.31123	.95033	.32777	.94476	52
9	.26135	.96524	.27815	.96054	.29487	.95554	.31151	.95024	.32804	.94466	51
10	.26163	.96517	.27843	.96046	.29515	.95545	.31178	.95015	.32832	.94457	50
11	.26191	.96509	.27871	.96037	.29543	.95536	.31206	.95006	.32859	.94447	49
12	.26219	.96502	.27899	.96029	.29571	.95528	.31233	.94997	.32887	.94438	48
13	.26247	.96494	.27927	.96021	.29599	.95519	.31261	.94988	.32914	.94428	47
14	.26275	.96486	.27955	.96013	.29626	.95511	.31289	.94979	.32942	.94418	46
15	.26303	.96479	.27983	.96005	.29654	.95502	.31316	.94970	.32969	.94409	45
16	.26331	.96471	.28011	.95997	.29682	.95493	.31344	.94961	.32997	.94399	44
17	.26359	.96463	.28039	.95989	.29710	.95485	.31372	.94952	.33024	.94390	43
18	.26387	.96456	.28067	.95981	.29737	.95476	.31399	.94943	.33051	.94380	42
19	.26415	.96448	.28095	.95972	.29765	.95467	.31427	.94933	.33079	.94370	41
20	.26443	.96440	.28123	.95964	.29793	.95459	.31454	.94924	.33106	.94361	40
21	.26471	.96433	.28150	.95956	.29821	.95450	.31482	.94915	.33134	.94351	39
22	.26500	.96425	.28178	.95948	.29849	.95441	.31510	.94906	.33161	.94342	38
23	.26528	.96417	.28206	.95940	.29876	.95433	.31537	.94897	.33189	.94332	37
24	.26556	.96110	.28234	.95931	.29904	.95424	.31565	.94888	.33216	.94322	36
25	.26584	.96402	.28262	.95923	.29932	.95415	.31593	.94878	.33244	.94313	35
26	.26612	.96394	.28290	.95915	.29960	.95407	.31620	.94869	.33271	.94303	34
27	.26640	.96386	.28318	.95907	.29987	.95398	.31648	.94860	.33298	.94293	33
28	.26668	.96379	.28346	.95898	.30015	.95389	.31675	.94851	.33326	.94284	32
29	.26696	.96371	.28374	.95890	.30043	.95380	.31703	.94842	.33353	.94274	31
30	.26724	.96363	.28402	.95882	.30071	.95372	.31730	.94832	.33381	.94264	30
31	.26752	.96355	.28429	.95874	.30098	.95363	.31758	.94823	.33408	.94254	20
32	.26780	.96347	.28457	.95865	.30126	.95354	.31786	.94814	.33436	.94245	28
33	.26808	.96340	.28485	.95857	.30154	.95345	.31813	.94805	.33463	.94235	27
34	.26836	.96332	.28513	.95849	.30182	.95337	.31841	.94795	.33490	.94225	26
35	.26864	.96324	.28541	.95841	.30209	.95328	.31868	.94786	.33518	.94215	25
36	.26892	.96316	.28569	.95832	.30237	.95319	.31896	.94777	.33545	.94206	24
37	.26920	.96308	.28597	.95824	.30265	.95310	.31923	.94768	.33573	.94196	23
38	.26948	.96301	.28625	.95816	.30292	.95301	.31951	.94758	.33600	.94186	22
39	.26976	.96293	.28652	.95807	.30320	.95293	.31979	.94749	.33627	.94176	21
40	.27004	.96285	.28680	.95799	.30348	.95284	.32006	.94740	.33655	.94167	20
41	.27032	.96277	.28708	.95791	.30376	.95275	.32034	.94730	.33682	.94157	19
42	.27060	.96269	.28736	.95782	.30403	.95266	.32061	.94721	.33710	.94147	18
43	.27088	.96261	.28764	.95774	.30431	.95257	.32089	.94712	.33737	.94137	17
44	.27116	.96253	.28792	.95766	.30459	.95248	.32116	.94702	.33764	.94127	16
45	.27144	.96246	.28820	.95757	.30486	.95240	.32144	.94693	.33792	.94118	15
46	.27172	.96238	.28847	.95749	.30514	.95231	.32171	.94684	.33819	.94108	14
47	.27200	.96230	.28875	.95740	.30542	.95222	.32199	.94674	.33846	.94098	13
48	.27228	.96222	.28903	.95732	.30570	.95213	.32227	.94665	.33874	.94088	12
49	.27256	.96214	.28931	.95724	.30597	.95204	.32254	.94656	33901	.94078	11
50	.27284	.96206	.28959	.95715	.30625	.95195	.32282	.94646	.33929	.94068	10
51	.27312	.96198	.28987	.95707	.30653	.95186	.32309	.94637	.33956	.94058	9
52	.27340	.96190	.29015	.95698	.30680	.95177	.32337	.94627	.33983	.94049	8
53	.27368	.96182	.29042	.95690	.30708	.95168	.32364	.94618	.34011	.94039	7
54	.27396	.96174	.29070	.95681	.30736	.95159	.32392	.94609	.34038	.94029	6
55	.27424	.96166	.29098	.95673	.30763	.95150	.32419	.94599	.34065	.94019	5
56	.27452	.96158	.29126	.95664	.30791	.95142	.32447	.94590	.34093	.94009	4
57	.27480	.96150	.29154	.95656	.30819	.95133	.32474	.94580	.34120	.93999	3
58	.27508	.96142	.29182	.95647	.30846	.95124	.32502	.94571	.34147	.93989	2
59	.27536	.96134	.29209	.95639	.30874	.95115	.32529	.94561	.34175	.93979	1
60	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	74°		73°		72°		71°		70°		

′	20°		21°		22°		23°		24°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.34202	.93969	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.34229	.93959	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.34257	.93949	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.34284	.93939	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.34311	.93929	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.34339	.93919	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.34366	.93909	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.34393	.93899	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.34421	.93889	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.34448	.93879	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.34475	.93869	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.34503	.93859	36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.34530	.93849	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.34557	.93839	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.34584	.93829	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.34612	.93819	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.34639	.93809	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.34666	.93799	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.34694	.93789	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.34721	.93779	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.34748	.93769	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.34775	.93759	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.34803	.93748	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.34830	.93738	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.34857	.93728	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.34884	.93718	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.34912	.93708	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.34939	.93698	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.34966	.93688	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.34993	.93677	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.35021	.93667	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.35048	.93657	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.35075	.93647	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.35102	.93637	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.35130	.93626	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.35157	.93616	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.35184	.93606	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.35211	93596	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.35239	.93585	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.35266	.93575	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.35293	.93565	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.35320	.93555	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.35347	.93544	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.35375	.93534	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.35402	.93524	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.35429	.93514	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.35456	.93503	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.35484	.93493	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.35511	.93483	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.35538	.93472	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.35565	.93462	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.35592	.93452	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.35619	.93441	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.35647	.93431	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.35674	.93420	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.35701	.93410	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.35728	.93400	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.35755	.93389	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.35782	.93379	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.35810	.93368	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	69°		68°		67°		66°		65°		

′	25°		26°		27°		28°		29°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	60
1	.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	.48506	.87448	59
2	.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	.48532	.87434	58
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	.48557	.87420	57
4	.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	.48583	.87406	56
5	.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	.48608	.87391	55
6	.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	.48634	.87377	54
7	.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	.48659	.87363	53
8	.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	.48684	.87349	52
9	.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	.48710	.87335	51
10	.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	.48735	.87321	50
11	.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	.48761	.87306	49
12	.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	.48786	.87292	48
13	.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	.48811	.87278	47
14	.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	.48837	.87264	46
15	.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	.48862	.87250	45
16	.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	.48888	.87235	44
17	.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	.48913	.87221	43
18	.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	.48938	.87207	42
19	.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	.48964	.87193	41
20	.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	.48989	.87178	40
21	.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	.49014	.87164	39
22	.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	.49040	.87150	38
23	.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	.49065	.87136	37
24	.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	.49090	.87121	36
25	.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	.49116	.87107	35
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	.49141	.87093	34
27	.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	.49166	.87079	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	.49192	.87064	32
29	.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	.49217	.87050	31
30	.43051	.90259	.44620	.89493	.46175	.88701	.47716	.87882	.49242	.87036	30
31	.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	.49268	.87021	29
32	.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	.49293	87007	28
33	.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	.49318	.86993	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	.49344	.86978	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	.49369	.86964	25
36	.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	.49394	.86949	24
37	.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	.49419	.86935	23
38	.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	.49445	.86921	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	.49470	.86906	21
40	.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	.49495	.86892	20
41	.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	.49521	.86878	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	.49546	.86863	18
43	.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	.49571	.86849	17
44	.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	.49596	.86834	16
45	.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	.49622	.86820	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	.49647	.86805	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	.49672	.86791	13
48	.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	.49697	.86777	12
49	.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	.49723	.86762	11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	.49748	.86748	10
51	.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	.49773	.86733	9
52	.43628	.89981	.45192	.89206	.46742	.88404	.48277	.87575	.49798	.86719	8
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	.49824	.86704	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	.49849	.86690	6
55	.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	.49874	.86675	5
56	.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	.49899	.86661	4
57	.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	.49924	.86646	3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	.49950	.86632	
59	.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	.49975	.86617	
60	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	.50000	.86603	
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	64°		63°		62°		61°		60°		

′	30°		31°		32°		33°		34°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	60
1	.50025	.86588	.51529	.85702	.53017	.84789	.54488	.83851	.55943	.82887	59
2	.50050	.86573	.51554	.85687	.53041	.84774	.54513	.83835	.55968	.82871	58
3	.50076	.86559	.51579	.85672	.53066	.84759	.54537	.83819	.55992	.82855	57
4	.50101	.86544	.51604	.85657	.53091	.84743	.54561	.83804	.56016	.82839	56
5	.50126	.86530	.51628	.85642	.53115	.84728	.54586	.83788	.56040	.82822	55
6	.50151	.86515	.51653	.85627	.53140	.84712	.54610	.83772	.56064	.82806	54
7	.50176	.86501	.51678	.85612	.53164	.84697	.54635	.83756	.56088	.82790	53
8	.50201	.86486	.51703	.85597	.53189	.84681	.54659	.83740	.56112	.82773	52
9	.50227	.86471	.51728	.85582	.53214	.84666	.54683	.83724	.56136	.82757	51
10	.50252	.86457	.51753	.85567	.53238	.84650	.54708	.83708	.56160	.82741	50
11	.50277	.86442	.51778	.85551	.53263	.84635	.54732	.83692	.56184	.82724	49
12	.50302	.86427	.51803	.85536	.53288	.84619	.54756	.83676	.56208	.82708	48
13	.50327	.86413	.51828	.85521	.53312	.84604	.54781	.83660	.56232	.82692	47
14	.50352	.86398	.51852	.85506	.53337	.84588	.54805	.83645	.56256	.82675	46
15	.50377	.86384	.51877	.85491	.53361	.84573	.54829	.83629	.56280	.82659	45
16	.50403	.86369	.51902	.85476	.53386	.84557	.54854	.83613	.56305	.82643	44
17	.50428	.86354	.51927	.85461	.53411	.84542	.54878	.83597	.56329	.82626	43
18	.50453	.86340	.51952	.85446	.53435	.84526	.54902	.83581	.56353	.82610	42
19	.50478	.86325	.51977	.85431	.53460	.84511	.54927	.83565	.56377	.82593	41
20	.50503	.86310	.52002	.85416	.53484	.84495	.54951	.83549	.56401	.82577	40
21	.50528	.86295	.52026	.85401	.53509	.84480	.54975	.83533	.56425	.82561	39
22	.50553	.86281	.52051	.85385	.53534	.84464	.54999	.83517	.56449	.82544	38
23	.50578	.86266	.52076	.85370	.53558	.84448	.55024	.83501	.56473	.82528	37
24	.50603	.86251	.52101	.85355	.53583	.84433	.55048	.83485	.56497	.82511	36
25	.50628	.86237	.52126	.85340	.53607	.84417	.55072	.83469	.56521	.82495	35
26	.50654	.86222	.52151	.85325	.53632	.84402	.55097	.83453	.56545	.82478	34
27	.50679	.86207	.52175	.85310	.53656	.84386	.55121	.83437	.56569	.82462	33
28	.50704	.86192	.52200	.85294	.53681	.84370	.55145	.83421	.56593	.82446	32
29	.50729	.86178	.52225	.85279	.53705	.84355	.55169	.83405	.56617	.82429	31
30	.50754	.86163	.52250	.85264	.53730	.84339	.55194	.83389	.56641	.82413	30
31	.50779	.86148	.52275	.85249	.53754	.84324	.55218	.83373	.56665	.82396	29
32	.50804	.86133	.52299	.85234	.53779	.84308	.55242	.83356	.56689	.82380	28
33	.50829	.86119	.52324	.85218	.53804	.84292	.55266	.83340	.56713	.82363	27
34	.50854	.86104	.52349	.85203	.53828	.84277	.55291	.83324	.56736	.82347	26
35	.50879	.86089	.52374	.85188	.53853	.84261	.55315	.83308	.56760	.82330	25
36	.50904	.86074	.52399	.85173	.53877	.84245	.55339	.83292	.56784	.82314	24
37	.50929	.86059	.52423	.85157	.53902	.84230	.55363	.83276	.56808	.82297	23
38	.50954	.86045	.52448	.85142	.53926	.84214	.55388	.83260	.56832	.82281	22
39	.50979	.86030	.52473	.85127	.53951	.84198	.55412	.83244	.56856	.82264	21
40	.51004	.86015	.52498	.85112	.53975	.84182	.55436	.83228	.56880	.82248	20
41	.51029	.86000	.52522	.85096	.54000	.84167	.55460	.83212	.56904	.82231	19
42	.51054	.85985	.52547	.85081	.54024	.84151	.55484	.83195	.56928	.82214	18
43	.51079	.85970	.52572	.85066	.54049	.84135	.55509	.83179	.56952	.82198	17
44	.51104	.85956	.52597	.85051	.54073	.84120	.55533	.83163	.56976	.82181	16
45	.51129	.85941	.52621	.85035	.54097	.84104	.55557	.83147	.57000	.82165	15
46	.51154	.85926	.52646	.85020	.54122	.84088	.55581	.83131	.57024	.82148	14
47	.51179	.85911	.52671	.85005	.54146	.84072	.55605	.83115	.57047	.82132	13
48	.51204	.85896	.52696	.84989	.54171	.84057	.55630	.83098	.57071	.82115	12
49	.51229	.85881	.52720	.84974	.54195	.84041	.55654	.83082	.57095	.82098	11
50	.51254	.85866	.52745	.84959	.54220	.84025	.55678	.83066	.57119	.82082	10
51	.51279	.85851	.52770	.84943	.54244	.84009	.55702	.83050	.57143	.82065	9
52	.51304	.85836	.52794	.84928	.54269	.83994	.55726	.83034	.57167	.82048	8
53	.51329	.85821	.52819	.84913	.54293	.83978	.55750	.83017	.57191	.82032	7
54	.51354	.85806	.52844	.84897	.54317	.83962	.55775	.83001	.57215	.82015	6
55	.51379	.85792	.52869	.84882	.54342	.83946	.55799	.82985	.57238	.81999	5
56	.51404	.85777	.52893	.84866	.54366	.83930	.55823	.82969	.57262	.81982	4
57	.51429	.85762	.52918	.84851	.54391	.83915	.55847	.82953	.57286	.81965	3
58	.51454	.85747	.52943	.84836	.54415	.83899	.55871	.82936	.57310	.81949	2
59	.51479	.85732	.52967	.84820	.54440	.83883	.55895	.82920	.57334	.81932	1
60	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	.57358	.81915	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.57358	.81915	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	60
1	.57381	.81899	.58802	.80885	.60205	.79846	.61589	.78783	.62955	.77696	59
2	.57405	.81882	.58826	.80867	.60228	.79829	.61612	.78765	.62977	.77678	58
3	.57429	.81865	.58849	.80850	.60251	.79811	.61635	.78747	.63000	.77660	57
4	.57453	.81848	.58873	.80833	.60274	.79793	.61658	.78729	.63022	.77641	56
5	.57477	.81832	.58896	.80816	.60298	.79776	.61681	.78711	.63045	.77623	55
6	.57501	.81815	.58920	.80799	.60321	.79758	.61704	.78694	.63068	.77605	54
7	.57524	.81798	.58943	.80782	.60344	.79741	.61726	.78676	.63090	.77586	53
8	.57548	.81782	.58967	.80765	.60367	.79723	.61749	.78658	.63113	.77568	52
9	.57572	.81765	.58990	.80748	.60390	.79706	.61772	.78640	.63135	.77550	51
10	.57596	.81748	.59014	.80730	.60414	.79688	.61795	.78622	.63158	.77531	50
11	.57619	.81731	.59037	.80713	.60437	.79671	.61818	.78604	.63180	.77513	49
12	.57643	.81714	.59061	.80696	.60460	.79653	.61841	.78586	.63203	.77494	48
13	.57667	.81698	.59084	.80679	.60483	.79635	.61864	.78568	.63225	.77476	47
14	.57691	.81681	.59108	.80662	.60506	.79618	.61887	.78550	.63248	.77458	46
15	.57715	.81664	.59131	.80644	.60529	.79600	.61909	.78532	.63271	.77439	45
16	.57738	.81647	.59154	.80627	.60553	.79583	.61932	.78514	.63293	.77421	44
17	.57762	.81631	.59178	.80610	.60576	.79565	.61955	.78496	.63316	.77402	43
18	.57786	.81614	.59201	.80593	.60599	.79547	.61978	.78478	.63338	.77384	42
19	.57810	.81597	.59225	.80576	.60622	.79530	.62001	.78460	.63361	.77366	41
20	.57833	.81580	.59248	.80558	.60645	.79512	.62024	.78442	.63383	.77347	40
21	.57857	.81563	.59272	.80541	.60668	.79494	.62046	.78424	.63406	.77329	39
22	.57881	.81546	.59295	.80524	.60691	.79477	.62069	.78405	.63428	.77310	38
23	.57904	.81530	.59318	.80507	.60714	.79459	.62092	.78387	.63451	.77292	37
24	.57928	.81513	.59342	.80489	.60738	.79441	.62115	.78369	.63473	.77273	36
25	.57952	.81496	.59365	.80472	.60761	.79424	.62138	.78351	.63496	.77255	35
26	.57976	.81479	.59389	.80455	.60784	.79406	.62160	.78333	.63518	.77236	34
27	.57999	.81462	.59412	.80438	.60807	.79388	.62183	.78315	.63540	.77218	33
28	.58023	.81445	.59436	.80420	.60830	.79371	.62206	.78297	.63563	.77199	32
29	.58047	.81428	.59459	.80403	60853	.79353	.62229	.78279	.63585	.77181	31
30	.58070	.81412	.59482	.80386	.60876	.79335	.62251	.78261	.63608	.77162	30
31	.58094	.81395	.59506	.80368	.60899	.79318	.62274	.78243	.63630	.77144	29
32	.58118	.81378	.59529	.80351	.60922	.79300	.62297	.78225	.63653	.77125	28
33	.58141	.81361	.59552	.80334	.60945	.79282	.62320	.78206	.63675	.77107	27
34	.58165	.81344	.59576	.80316	.60968	.79264	.62342	.78188	.63698	.77088	26
35	.58189	.81327	.59599	.80299	.60991	.79247	.62365	.78170	.63720	.77070	25
36	.58212	.81310	.59622	.80282	.61015	.79229	.62388	.78152	.63742	.77051	24
37	.58236	.81293	.59646	.80264	.61038	.79211	.62411	.78134	.63765	.77033	23
38	.58260	.81276	.59669	.80247	.61061	.79193	.62433	.78116	.63787	.77014	22
39	.58283	.81259	.59693	.80230	.61084	.79176	.62456	.78098	.63810	.76996	21
40	.58307	.81242	.59716	.80212	.61107	.79158	.62479	.78079	.63832	.76977	20
41	.58330	.81225	.59739	.80195	.61130	.79140	.62502	.78061	.63854	.76959	19
42	.58354	.81208	.59763	.80178	.61153	.79122	.62524	.78043	.63877	.76940	18
43	.58378	.81191	.59786	.80160	.61176	.79105	.62547	.78025	.63899	.76921	17
44	.58401	.81174	.59809	.80143	.61199	.79087	.62570	.78007	.63922	.76903	16
45	.58425	.81157	.59832	.80125	.61222	.79069	.62592	.77988	.63944	.76884	15
46	.58449	.81140	.59856	.80108	.61245	.79051	.62615	.77970	.63966	.76866	14
47	.58472	.81123	.59879	.80091	.61268	.79033	.62638	.77952	.63989	.76847	13
48	.58496	.81106	.59902	.80073	.61291	.79016	.62660	.77934	.64011	.76828	12
49	.58519	.81089	.59926	.80056	.61314	.78998	.62683	.77916	.64033	.76810	11
50	.58543	.81072	.59949	.80038	.61337	.78980	.62706	.77897	.64056	.76791	10
51	.58567	.81055	.59972	.80021	.61360	.78962	.62728	.77879	.64078	.76772	9
52	.58590	.81038	.59995	.80003	.61383	.78944	.62751	.77861	.64100	.76754	8
53	.58614	.81021	.60019	.79986	.61406	.78926	.62774	.77843	.64123	.76735	7
54	.58637	.81004	.60042	.79968	.61429	.78908	.62796	.77824	.64145	.76717	6
55	.58661	.80987	.60065	.79951	.61451	.78891	.62819	.77806	.64167	.76698	5
56	.58684	.80970	.60089	.79934	.61474	.78873	.62842	.77788	.64190	.76679	4
57	.58708	.80953	.60112	.79916	.61497	.78855	.62864	.77769	.64212	.76661	3
58	.58731	.80936	.60135	.79899	.61520	.78837	.62887	.77751	.64234	.76642	2
59	.58755	.80919	.60158	.79881	.61543	.78819	.62909	.77733	.64256	.76623	1
60	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.64279	.76604	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
1	.64301	.76586	.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
2	.64323	.76567	.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
3	.64346	.76548	.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
4	.64368	.76530	.65694	.75395	.66999	.74237	.68285	.73056	.69549	.71853	56
5	.64390	.76511	.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
6	.64412	.76492	.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
7	.64435	.76473	.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
8	.64457	.76455	.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
9	.64479	.76436	.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
10	.64501	.76417	.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
11	.64524	.76398	.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
12	.64546	.76380	.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
13	.64568	.76361	.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
14	.64590	.76342	.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
15	.64612	.76323	.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
16	.64635	.76304	.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
17	.64657	.76286	.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
18	.64679	.76267	.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
19	.64701	.76248	.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
20	.64723	.76229	.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
21	.64746	.76210	.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
22	.64768	.76192	.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
23	.64790	.76173	.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
24	.64812	.76154	.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
25	.64834	.76135	.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
26	.64856	.76116	.66175	.74973	.67473	.73806	.68751	.72617	.70008	.71407	34
27	.64878	.76097	.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
28	.64901	.76078	.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
29	.64923	.76059	.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
30	.64945	.76041	.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
31	.64967	.76022	.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
32	.64989	.76003	.66306	.74857	.67602	.73688	.68878	.72497	.70132	.71284	28
33	.65011	.75984	.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
34	.65033	.75965	.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
35	.65055	.75946	.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
36	.65077	.75927	.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
37	.65100	.75908	.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
38	.65122	.75889	.66436	.74741	.67730	.73570	.69004	.72377	.70257	.71162	22
39	.65144	.75870	.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
40	.65166	.75851	.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
41	.65188	.75832	.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
42	.65210	.75813	.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
43	.65232	.75794	.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
44	.65254	.75775	.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
45	.65276	.75756	.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
46	.65298	.75738	.66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
47	.65320	.75719	.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
48	.65342	.75700	.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
49	.65364	.75680	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
50	.65386	.75661	.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
51	.65408	.75642	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.65430	.75623	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.65452	.75604	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.65474	.75585	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.65496	.75566	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.65518	.75547	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
57	.65540	.75528	.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
58	.65562	.75509	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.65584	.75490	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	49°		48°		47°		46°		45°		

′	0°		1°		2°		3°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.00000	Infinite.	.01746	57.2900	.03492	28.6363	.05241	19.0811	60
1	.00029	3437.75	.01775	56.3506	.03521	28.3994	.05270	18.9755	59
2	.00058	1718.87	.01804	55.4415	.03550	28.1664	.05299	18.8711	58
3	.00087	1145.92	.01833	54.5613	.03579	27.9372	.05328	18.7678	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	33
28	.00815	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	[redacted]	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	[redacted]	25
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	15
46	.01338	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1893	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	9
52	.01513	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	5
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	4
57	.01658	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	3
58	.01687	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	1
60	*.01746*	*57.2900*	.03492	28.6363	.05241	19.0811	.06993	14.3007	
′	*Cotang*	*Tang*	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	89°		**88°**		**87°**		**86°**		

′	4°		5°		6°		7°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.06993	14.3007	.08749	11.4301	.10510	9.51436	.12278	8.14435	60
1	.07022	14.2411	.08778	11.3919	.10540	9.48781	.12308	8.12481	59
2	.07051	14.1821	.08807	11.3540	.10569	9.46141	.12338	8.10536	58
3	.07080	14.1235	.08837	11.3163	.10599	9.43515	.12367	8.08600	57
4	.07110	14.0655	.08866	11.2789	.10628	9.40904	.12397	8.06674	56
5	.07139	14.0079	.08895	11.2417	.10657	9.38307	.12426	8.04756	55
6	.07168	13.9507	.08925	11.2048	.10687	9.35724	.12456	8.02848	54
7	.07197	13.8940	.08954	11.1681	.10716	9.33155	.12485	8.00948	53
8	.07227	13.8378	.08983	11.1316	.10746	9.30599	.12515	7.99058	52
9	.07256	13.7821	.09013	11.0954	.10775	9.28058	.12544	7.97176	51
10	.07285	13.7267	.09042	11.0594	.10805	9.25530	.12574	7.95302	50
11	.07314	13.6719	.09071	11.0237	.10834	9.23016	.12603	7.93438	49
12	.07344	13.6174	.09101	10.9882	.10863	9.20516	.12633	7.91582	48
13	.07373	13.5634	.09130	10.9529	.10893	9.18028	.12662	7.89734	47
14	.07402	13.5098	.09159	10.9178	.10922	9.15554	.12692	7.87895	46
15	.07431	13.4566	.09189	10.8829	.10952	9.13093	.12722	7.86064	45
16	.07461	13.4039	.09218	10.8483	.10981	9.10646	.12751	7.84242	44
17	.07490	13 3515	.09247	10.8139	.11011	9.08211	.12781	7.82428	43
18	.07519	13.2996	.09277	10.7797	.11040	9.05789	.12810	7.80622	42
19	.07548	13.2480	.09306	10.7457	.11070	9.03379	.12840	7.78825	41
20	.07578	13.1969	.09335	10.7119	.11099	9.00983	.12869	7.77035	40
21	.07607	13.1461	.09365	10.6783	.11128	8.98598	.12899	7.75254	39
22	.07636	13.0958	.09394	10.6450	.11158	8.96227	.12929	7.73480	38
23	.07665	13.0458	.09423	10.6118	.11187	8.93867	.12958	7.71715	37
24	.07695	12.9962	.09453	10.5789	.11217	8.91520	.12988	7.69957	36
25	.07724	12.9469	.09482	10.5462	.11246	8.89185	.13017	7.68208	35
26	.07753	12.8981	.09511	10.5136	.11276	8.86862	.13047	7.66466	34
27	.07782	12.8496	.09541	10.4813	.11305	8.84551	.13076	7.64732	33
28	.07812	12.8014	.09570	10.4491	.11335	8.82252	.13106	7.63005	32
29	.07841	12.7536	.09600	10.4172	.11364	8.79964	.13136	7.61287	31
30	.07870	12.7062	.09629	10.3854	.11394	8.77689	.13165	7.59575	30
31	.07899	12.6591	.09658	10.3538	.11423	8.75425	.13195	7.57872	29
32	.07929	12.6124	.09688	10.3224	.11452	8.73172	.13224	7.56176	28
33	.07958	12.5660	.09717	10.2913	.11482	8.70931	.13254	7.54487	27
34	.07987	12.5199	.09746	10.2602	.11511	8.68701	.13284	7.52806	26
35	.08017	12.4742	.09776	10.2294	.11541	8.66482	.13313	7.51132	25
36	.08046	12.4288	.09805	10.1988	.11570	8.64275	.13343	7.49465	24
37	.08075	12.3838	.09834	10.1683	.11600	8.62078	.13372	7.47806	23
38	.08104	12.3390	.09864	10.1381	.11629	8.59893	.13402	7.46154	22
39	.08134	12.2946	.09893	10.1080	.11659	8.57718	.13432	7.44509	21
40	.08163	12.2505	.09923	10.0780	.11688	8.55555	.13461	7.42871	20
41	.08192	12.2067	.09952	10.0483	.11718	8.53402	.13491	7.41240	19
42	.08221	12.1632	.09981	10.0187	.11747	8.51259	.13521	7.39616	18
43	.08251	12.1201	.10011	9.98931	.11777	8.49128	.13550	7.37999	17
44	.08280	12.0772	.10040	9.96007	.11806	8.47007	.13580	7.36389	16
45	.08309	12.0346	.10069	9.93101	.11836	8.44896	.13609	7.34786	15
46	.08339	11.9923	.10099	9.90211	.11865	8.42795	.13639	7.33190	14
47	.08368	11.9504	.10128	9.87338	.11895	8.40705	.13669	7.31600	13
48	.08397	11.9087	.10158	9.84482	.11924	8.38625	.13698	7.30018	12
49	.08427	11.8673	.10187	9.81641	.11954	8.36555	.13728	7.28442	11
50	.08456	11.8262	.10216	9.78817	.11983	8.34496	.13758	7.26873	10
51	.08485	11.7853	.10246	9.76009	.12013	8.32446	.13787	7.25310	9
52	.08514	11.7448	.10275	9.73217	.12042	8.30406	.13817	7.23754	8
53	.08544	11.7045	.10305	9.70441	.12072	8.28376	.13846	7.22204	7
54	.08573	11.6645	.10334	9.67680	.12101	8.26355	.13876	7.20661	6
55	.08602	11.6248	.10363	9.64935	.12131	8.24345	.13906	7.19125	5
56	.08632	11.5853	.10393	9.62205	.12160	8.22344	.13935	7.17594	4
57	.08661	11.5461	.10422	9.59490	.12190	8.20352	.13965	7.16071	3
58	.08690	11 5072	.10452	9.56791	.12219	8.18370	.13995	7.14553	2
59	.08720	11.4685	.10481	9.54106	.12249	8.16398	.14024	7.13042	1
60	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	85°		84°		83°		82°		

88°					89°			
Vers.	D. 1".	Ex. sec.	q+l	′	Vers.	D. 1".	Ex. sec.	q+l
			15.29*					15.30*
9.984573	2.17	11.441753	9086	0	9.992354	2.13	11.750498	6801
.984703	2.18	.445517	9215	1	.992482	2.15	.757925	6929
.984834	2.18	.449311	9345	2	.992611	2.13	.765477	7056
.984965	2.18	.453137	9474	3	.992739	2.15	.773158	7184
.985096	2.17	.456994	9603	4	.992868	2.13	.780973	7312
.985226	2.18	.460883	9732	5	.992996	2.13	.788926	7440
.985357	2.17	.464805	9862	6	.993124	2.15	.797022	7567
.985487	2.18	.468761	9991	7	.993253	2.13	.805268	7695
.985618	2.17	.472751	◆120	8	.993381	2.13	.813668	7823
.985748	2.18	.476775	0249	9	.993509	2.13	.822229	7950
.985879	2.17	.480834	0378	10	.993637	2.13	.830956	8078
9.986009	2.18	11.484929	0507	11	9.993765	2.15	11.839858	8205
.986140	2.17	.489061	0636	12	.993894	2.13	.848940	8333
.986270	2.17	.493230	0765	13	.994022	2.13	.858211	8460
.986400	2.18	.497437	0894	14	.994150	2.13	.867679	8588
.986531	2.17	.501683	1023	15	.994278	2.13	.877351	8715
.986661	2.17	.505968	1152	16	.994406	2.13	.887239	8843
.986791	2.17	.510293	1281	17	.994534	2.13	.897350	8970
.986921	2.17	.514659	1410	18	.994662	2.12	.907697	9097
.987051	2.17	.519066	1539	19	.994789	2.13	.918290	9225
.987181	2.17	.523516	1668	20	.994917	2.13	.929141	9352
9.987311	2.17	11.528010	1797	21	9.995045	2.13	11.940264	9479
.987441	2.17	.532548	1925	22	.995173	2.13	.951672	9607
.987571	2.17	.537131	2054	23	.995301	2.12	.963381	9734
.987701	2.17	.541760	2183	24	.995428	2.13	.975408	9862
.987831	2.17	.546437	2312	25	.995556	2.12	11.987769	9988
.987961	2.17	.551161	2440	26	.995688	2.13	12.000485	◆116
.988091	2.17	.555935	2569	27	.995811	2.13	.013578	0243
.988221	2.15	.560759	2698	28	.995939	2.12	.027069	0370
.988350	2.17	.565634	2826	29	.996066	2.12	.040984	0497
.988480	2.17	.570561	2955	30	.996193	2.13	.055352	0624
9.988610	2.15	11.575542	3083	31	9.996321	2.12	12.070202	0751
.988739	2.17	.580578	3212	32	.996448	2.13	.085569	0878
.988869	2.15	.585670	3340	33	.996576	2.12	.101490	1005
.988998	2.17	.590819	3469	34	.996703	2.12	.118008	1132
.989128	2.15	.596027	3597	35	.996830	2.12	.135168	1259
.989257	2.17	.601295	3726	36	.996957	2.13	.153024	1386
.989387	2.15	.606625	3854	37	.997085	2.12	.171634	1513
.989516	2.17	.612018	3983	38	.997212	2.12	.191068	1640
.989646	2.15	.617475	4111	39	.997339	2.12	.211396	1767
.989775	2.15	.622998	4239	40	.997466	2.12	.232712	1894
9.989904	2.17	11.628589	4368	41	9.997593	2.12	12.255116	2020
.990034	2.15	.634250	4496	42	.997720	2.12	.278723	2147
.990163	2.15	.639982	4624	43	.997847	2.12	.303674	2274
.990292	2.15	.645788	4752	44	.997974	2.12	.330129	2401
.990421	2.15	.651668	4881	45	.998101	2.12	.358285	2527
.990550	2.15	.657626	5009	46	.998228	2.12	.388375	2654
.990679	2.15	.663663	5137	47	.998355	2.10	.420686	2781
.990808	2.15	.669781	5265	48	.998481	2.12	.455575	2907
.990937	2.15	.675984	5393	49	.998608	2.12	.493490	3034
.991066	2.15	.682272	5521	50	.998735	2.12	.535009	3161
9.991195	2.15	11.688649	5649	51	9.998862	2.10	12.580893	3287
.991324	2.15	.695117	5777	52	.998988	2.12	.632172	3414
.991453	2.15	.701679	5905	53	.999115	2.10	.690291	3540
.991582	2.13	.708338	6033	54	.999241	2.12	.757364	3667
.991710	2.15	.715097	6161	55	.999368	2.10	.836672	3793
.991839	2.15	.721958	6289	56	.999494	2.12	12.933708	3920
.991968	2.13	.728925	6417	57	.999621	2.10	13.058774	4046
.992096	2.15	.736002	6545	58	.999747	2.12	.234991	4172
.992225	2.15	.743192	6673	59	.999874	2.10	.536148	4299
9.992354	2.13	11.750498	6801	60	10.000000	2.10	Inf. pos.	4426
			15.30*					15.31*

′	12°		13°		14°		15°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	60
1	.21286	4.69791	.23117	4.32573	.24964	4.00582	.26826	3.72771	59
2	.21316	4.69121	.23148	4.32001	.24995	4.00086	.26857	3.72338	58
3	.21347	4.68452	.23179	4.31430	.25026	3.99592	.26888	3.71907	57
4	.21377	4.67786	.23209	4.30860	.25056	3.99099	.26920	3.71476	56
5	.21408	4.67121	.23240	4.30291	.25087	3.98607	.26951	3.71046	55
6	.21438	4.66458	.23271	4.29724	.25118	3.98117	.26982	3.70616	54
7	.21469	4.65797	.23301	4.29159	.25149	3.97627	.27013	3.70188	53
8	.21499	4.65138	.23332	4.28595	.25180	3.97139	.27044	3.69761	52
9	.21529	4.64480	.23363	4.28032	.25211	3.96651	.27076	3.69335	51
10	.21560	4.63825	.23393	4.27471	.25242	3.96165	.27107	3.68909	50
11	.21590	4.63171	.23424	4.26911	.25273	3.95680	.27138	3.68485	49
12	.21621	4.62518	.23455	4.26352	.25304	3.95196	.27169	3.68061	48
13	.21651	4.61868	.23485	4.25795	.25335	3.94713	.27201	3.67638	47
14	.21682	4.61219	.23516	4.25239	.25366	3.94232	.27232	3.67217	46
15	.21712	4.60572	.23547	4.24685	.25397	3.93751	.27263	3.66796	45
16	.21743	4.59927	.23578	4.24132	.25428	3.93271	.27294	3.66376	44
17	.21773	4.59283	.23608	4.23580	.25459	3.92793	.27326	3.65957	43
18	.21804	4.58641	.23639	4.23030	.25490	3.92316	.27357	3.65538	42
19	.21834	4.58001	.23670	4.22481	.25521	3.91839	.27388	3.65121	41
20	.21864	4.57363	.23700	4.21933	.25552	3.91364	.27419	3.64705	40
21	.21895	4.56726	.23731	4.21387	.25583	3.90890	.27451	3.64289	39
22	.21925	4.56091	.23762	4.20842	.25614	3.90417	.27482	3.63874	38
23	.21956	4.55458	.23793	4.20298	.25645	3.89945	.27513	3.63461	37
24	.21986	4.54826	.23823	4.19756	.25676	3.89474	.27545	3.63048	36
25	.22017	4.54196	.23854	4.19215	.25707	3.89004	.27576	3.62636	35
26	.22047	4.53568	.23885	4.18675	.25738	3.88536	.27607	3.62224	34
27	.22078	4.52941	.23916	4.18137	.25769	3.88068	.27638	3.61814	33
28	.22108	4.52316	.23946	4.17600	.25800	3.87601	.27670	3.61405	32
29	.22139	4.51693	.23977	4.17064	.25831	3.87136	.27701	3.60996	31
30	.22169	4.51071	.24008	4.16530	.25862	3.86671	.27732	3.60588	30
31	.22200	4.50451	.24039	4.15997	.25893	3.86208	.27764	3.60181	29
32	.22231	4.49832	.24069	4.15465	.25924	3.85745	.27795	3.59775	28
33	.22261	4.49215	.24100	4.14934	.25955	3.85284	.27826	3.59370	27
34	.22292	4.48600	.24131	4.14405	.25986	3.84824	.27858	3.58966	26
35	.22322	4.47986	.24162	4.13877	.26017	3.84364	.27889	3.58562	25
36	.22353	4.47374	.24193	4.13350	.26048	3.83906	.27921	3.58160	24
37	.22383	4.46764	.24223	4.12825	.26079	3.83449	.27952	3.57758	23
38	.22414	4.46155	.24254	4.12301	.26110	3.82992	.27983	3.57357	22
39	.22444	4.45548	.24285	4.11778	.26141	3.82537	.28015	3.56957	21
40	.22475	4.44942	.24316	4.11256	.26172	3.82083	.28046	3.56557	20
41	.22505	4.44338	.24347	4.10736	.26203	3.81630	.28077	3.56159	19
42	.22536	4.43735	.24377	4.10216	.26235	3.81177	.28109	3.55761	18
43	.22567	4.43134	.24408	4.09699	.26266	3.80726	.28140	3.55364	17
44	.22597	4.42534	.24439	4.09182	.26297	3.80276	.28172	3.54968	16
45	.22628	4.41936	.24470	4.08666	.26328	3.79827	.28203	3.54573	15
46	.22658	4.41340	.24501	4.08152	.26359	3.79378	.28234	3.54179	14
47	.22689	4.40745	.24532	4.07639	.26390	3.78931	.28266	3.53785	13
48	.22719	4.40152	.24562	4.07127	.26421	3.78485	.28297	3.53393	12
49	.22750	4.39560	.24593	4.06616	.26452	3.78040	.28329	3.53001	11
50	.22781	4.38969	.24624	4.06107	.26483	3.77595	.28360	3.52609	10
51	.22811	4.38381	.24655	4.05599	.26515	3.77152	.28391	3.52219	9
52	.22842	4.37793	.24686	4.05092	.26546	3.76709	.28423	3.51829	8
53	.22872	4.37207	.24717	4.04586	.26577	3.76268	.28454	3.51441	7
54	.22903	4.36623	.24747	4.04081	.26608	3.75828	.28486	3.51053	6
55	.22934	4.36040	.24778	4.03578	.26639	3.75388	.28517	3.50666	5
56	.22964	4.35459	.24809	4.03076	.26670	3.74950	.28549	3.50279	4
57	.22995	4.34879	.24840	4.02574	.26701	3.74512	.28580	3.49894	3
58	.23026	4.34300	.24871	4.02074	.26733	3.74075	.28612	3.49509	2
59	.23056	4.33723	.24902	4.01576	.26764	3.73640	.28643	3.49125	1
60	.23087	4.33148	.24933	4.01078	.26795	3.73205	.28675	3.48741	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	77°		76°		75°		74°		

′	16° Tang	16° Cotang	17° Tang	17° Cotang	18° Tang	18° Cotang	19° Tang	19° Cotang	′
0	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	60
1	.28706	3.48359	.30605	3.26745	.32524	3.07464	.34465	2.90147	59
2	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
3	.28769	3.47596	.30669	3.26067	.32588	3.06857	.34530	2.89600	57
4	.28800	3.47216	.30700	3.25729	.32621	3.06554	.34563	2.89327	56
5	.28832	3.46837	.30732	3.25392	.32653	3.06252	.34596	2.89055	55
6	.28864	3.46458	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.28927	3.45703	.30828	3.24383	.32749	3.05349	.34693	2.88240	52
9	.28958	3.45327	.30860	3.24049	.32782	3.05049	.34726	2.87970	51
10	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35020	2.85555	42
19	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.29337	3.40869	.31242	3.20079	.33169	3.01489	.35118	2.84758	39
22	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.29590	3.37955	.31498	3.17481	.33427	2.99158	.35379	2.82653	31
30	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82391	30
31	.29653	3.37234	.31562	3.16838	33492	2.98580	.35445	2.82130	29
32	.29685	3.36875	.31594	3.16517	33524	2.98292	35477	2.81870	28
33	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.29748	3.36158	.31658	3.15877	.33589	2.97717	35543	2.81350	26
35	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.29811	3.35443	.31722	3.15240	.33654	2.97144	35608	2.80833	24
37	.29843	3.35087	.31754	3.14922	.33686	2.96858	35641	2.80574	23
38	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.29906	3.34377	.31818	3.14288	.33751	2.96288	.35707	2.80059	21
40	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.29970	3.33670	.31882	3.13656	.33816	2.95721	35772	2.79545	19
42	.30001	3.33317	.31914	3.13341	.33848	2.95437	35805	2.79289	18
43	.30033	3.32965	.31946	3.13027	.33881	2.95155	35838	2.79033	17
44	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.30097	3.32264	.32010	3.12400	.33945	2.94591	35904	2.78523	15
46	.30128	3.31914	.32042	3.12087	.33978	2.94309	35937	2.78269	14
47	.30160	3.31565	.32074	3.11775	.34010	2.94028	35969	2.78014	13
48	.30192	3.31216	.32106	3.11464	34043	2.93748	36002	2.77761	12
49	.30224	3.30868	.32139	3.11153	.34075	2.93468	36035	2.77507	11
50	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.30319	3.29829	.32235	3.10223	.34173	2.92632	.36134	2.76750	8
53	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76498	7
54	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.30414	3.28795	.32331	3.09298	.34270	2.91799	36232	2.75996	5
56	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	73°		72°		71°		70°		

′	10°		11°		12°		13°		14°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	60
1	.17393	.98476	.19109	.98157	.20820	.97809	.22523	.97430	.24220	.97023	59
2	.17422	.98471	.19138	.98152	.20848	.97803	.22552	.97424	.24249	.97015	58
3	.17451	.98466	.19167	.98146	.20877	.97797	.22580	.97417	.24277	.97008	57
4	.17479	.98461	.19195	.98140	.20905	.97791	.22608	.97411	.24305	.97001	56
5	.17508	.98455	.19224	.98135	.20933	.97784	.22637	.97404	.24333	.96994	55
6	.17537	.98450	.19252	.98129	.20962	.97778	.22665	.97398	.24362	.96987	54
7	.17565	.98445	.19281	.98124	.20990	.97772	.22693	.97391	.24390	.96980	53
8	.17594	.98440	.19309	.98118	.21019	.97766	.22722	.97384	.24418	.96973	52
9	.17623	.98435	.19338	.98112	.21047	.97760	.22750	.97378	.24446	.96966	51
10	.17651	.98430	.19366	.98107	.21076	.97754	.22778	.97371	.24474	.96959	50
11	.17680	.98425	.19395	.98101	.21104	.97748	.22807	.97365	.24503	.96952	49
12	.17708	.98420	.19423	.98096	.21132	.97742	.22835	.97358	.24531	.96945	48
13	.17737	.98414	.19452	.98090	.21161	.97735	.22863	.97351	.24559	.96937	47
14	.17766	.98409	.19481	.98084	.21189	.97729	.22892	.97345	.24587	.96930	46
15	.17794	.98404	.19509	.98079	.21218	.97723	.22920	.97338	.24615	.96923	45
16	.17823	.98399	.19538	.98073	.21246	.97717	.22948	.97331	.24644	.96916	44
17	.17852	.98394	.19566	.98067	.21275	.97711	.22977	.97325	.24672	.96909	43
18	.17880	.98389	.19595	.98061	.21303	.97705	.23005	.97318	.24700	.96902	42
19	.17909	.98383	.19623	.98056	.21331	.97698	.23033	.97311	.24728	.96894	41
20	.17937	.98378	.19652	.98050	.21360	.97692	.23062	.97304	.24756	.96887	40
21	.17966	.98373	.19680	.98044	.21388	.97686	.23090	.97298	.24784	.96880	39
22	.17995	.98368	.19709	.98039	.21417	.97680	.23118	.97291	.24813	.96873	38
23	.18023	.98362	.19737	.98033	.21445	.97673	.23146	.97284	.24841	.96866	37
24	.18052	.98357	.19766	.98027	.21474	.97667	.23175	.97278	.24869	.96858	36
25	.18081	.98352	.19794	.98021	.21502	.97661	.23203	.97271	.24897	.96851	35
26	.18109	.98347	.19823	.98016	.21530	.97655	.23231	.97264	.24925	.96844	34
27	.18138	.98341	.19851	.98010	.21559	.97648	.23260	.97257	.24954	.96837	33
28	.18166	.98336	.19880	.98004	.21587	.97642	.23288	.97251	.24982	.96829	32
29	.18195	.98331	.19908	.97998	.21616	.97636	.23316	.97244	.25010	.96822	31
30	.18224	.98325	.19937	.97992	.21644	.97630	.23345	.97237	.25038	.96815	30
31	.18252	.98320	.19965	.97987	.21672	.97623	.23373	.97230	.25066	.96807	29
32	.18281	.98315	.19994	.97981	.21701	.97617	.23401	.97223	.25094	.96800	28
33	.18309	.98310	.20022	.97975	.21729	.97611	.23429	.97217	.25122	.96793	27
34	.18338	.98304	.20051	.97969	.21758	.97604	.23458	.97210	.25151	.96786	26
35	.18367	.98299	.20079	.97963	.21786	.97598	.23486	.97203	.25179	.96778	25
36	.18395	.98294	.20108	.97958	.21814	.97592	.23514	.97196	.25207	.96771	24
37	.18424	.98288	.20136	.97952	.21843	.97585	.23542	.97189	.25235	.96764	23
38	.18452	.98283	.20165	.97946	.21871	.97579	.23571	.97182	.25263	.96756	22
39	.18481	.98277	.20193	.97940	.21899	.97573	.23599	.97176	.25291	.96749	21
40	.18509	.98272	.20222	.97934	.21928	.97566	.23627	.97169	.25320	.96742	20
41	.18538	.98267	.20250	.97928	.21956	.97560	.23656	.97162	.25348	.96734	19
42	.18567	.98261	.20279	.97922	.21985	.97553	.23684	.97155	.25376	.96727	18
43	.18595	.98256	.20307	.97916	.22013	.97547	.23712	.97148	.25404	.96719	17
44	.18624	.98250	.20336	.97910	.22041	.97541	.23740	.97141	.25432	.96712	16
45	.18652	.98245	.20364	.97905	.22070	.97534	.23769	.97134	.25460	.96705	15
46	.18681	.98240	.20393	.97899	.22098	.97528	.23797	.97127	.25488	.96697	14
47	.18710	.98234	.20421	.97893	.22126	.97521	.23825	.97120	.25516	.96690	13
48	.18738	.98229	.20450	.97887	.22155	.97515	.23853	.97113	.25545	.96682	12
49	.18767	.98223	.20478	.97881	.22183	.97508	.23882	.97106	.25573	.96675	11
50	.18795	.98218	.20507	.97875	.22212	.97502	.23910	.97100	.25601	.96667	10
51	.18824	.98212	.20535	.97869	.22240	.97496	.23938	.97093	.25629	.96660	9
52	.18852	.98207	.20563	.97863	.22268	.97489	.23966	.97086	.25657	.96653	8
53	.18881	.98201	.20592	.97857	.22297	.97483	.23995	.97079	.25685	.96645	7
54	.18910	.98196	.20620	.97851	.22325	.97476	.24023	.97072	.25713	.96638	6
55	.18938	.98190	.20649	.97845	.22353	.97470	.24051	.97065	.25741	.96630	5
56	.18967	.98185	.20677	.97839	.22382	.97463	.24079	.97058	.25769	.96623	4
57	.18995	.98179	.20706	.97833	.22410	.97457	.24108	.97051	.25798	.96615	3
58	.19024	.98174	.20734	.97827	.22438	.97450	.24136	.97044	.25826	.96608	2
59	.19052	.98168	.20763	.97821	.22467	.97444	.24164	.97037	.25854	.96600	1
60	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	.25882	.96593	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	79°		78°		77°		76°		75°		

′	15°		16°		17°		18°		19°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.25882	.96593	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	60
1	.25910	.96585	.27592	.96118	.29265	.95622	.30929	.95097	.32584	.94542	59
2	.25938	.96578	.27620	.96110	.29293	.95613	.30957	.95088	.32612	.94533	58
3	.25966	.96570	.27648	.96102	.29321	.95605	.30985	.95079	.32639	.94523	57
4	.25994	.96562	.27676	.96094	.29348	.95596	.31012	.95070	.32667	.94514	56
5	.26022	.96555	.27704	.96086	.29376	.95588	.31040	.95061	.32694	.94504	55
6	.26050	.96547	.27731	.96078	.29404	.95579	.31068	.95052	.32722	.94495	54
7	.26079	.96540	.27759	.96070	.29432	.95571	.31095	.95043	.32749	.94485	53
8	.26107	.96532	.27787	.96062	.29460	.95562	.31123	.95033	.32777	.94476	52
9	.26135	.96524	.27815	.96054	.29487	.95554	.31151	.95024	.32804	.94466	51
10	.26163	.96517	.27843	.96046	.29515	.95545	.31178	.95015	.32832	.94457	50
11	.26191	.96509	.27871	.96037	.29543	.95536	.31206	.95006	.32859	.94447	49
12	.26219	.96502	.27899	.96029	.29571	.95528	.31233	.94997	.32887	.94438	48
13	.26247	.96494	.27927	.96021	.29599	.95519	.31261	.94988	.32914	.94428	47
14	.26275	.96486	.27955	.96013	.29626	.95511	.31289	.94979	.32942	.94418	46
15	.26303	.96479	.27983	.96005	.29654	.95502	.31316	.94970	.32969	.94409	45
16	.26331	.96471	.28011	.95997	.29682	.95493	.31344	.94961	.32997	.94399	44
17	.26359	.96463	.28039	.95989	.29710	.95485	.31372	.94952	.33024	.94390	43
18	.26387	.96456	.28067	.95981	.29737	.95476	.31399	.94943	.33051	.94380	42
19	.26415	.96448	.28095	.95972	.29765	.95467	.31427	.94933	.33079	.94370	41
20	.26443	.96440	.28123	.95964	.29793	.95459	.31454	.94924	.33106	.94361	40
21	.26471	.96433	.28150	.95956	.29821	.95450	.31482	.94915	.33134	.94351	39
22	.26500	.96425	.28178	.95948	.29849	.95441	.31510	.94906	.33161	.94342	38
23	.26528	.96417	.28206	.95940	.29876	.95433	.31537	.94897	.33189	.94332	37
24	.26556	.96410	.28234	.95931	.29904	.95424	.31565	.94888	.33216	.94322	36
25	.26584	.96402	.28262	.95923	.29932	.95415	.31593	.94878	.33244	.94313	35
26	.26612	.96394	.28290	.95915	.29960	.95407	.31620	.94869	.33271	.94303	34
27	.26640	.96386	.28318	.95907	.29987	.95398	.31648	.94860	.33298	.94293	33
28	.26668	.96379	.28346	.95898	.30015	.95389	.31675	.94851	.33326	.94284	32
29	.26696	.96371	.28374	.95890	.30043	.95380	.31703	.94842	.33353	.94274	31
30	.26724	.96363	.28402	.95882	.30071	.95372	.31730	.94832	.33381	.94264	30
31	.26752	.96355	.28429	.95874	.30098	.95363	.31758	.94823	.33408	.94254	29
32	.26780	.96347	.28457	.95865	.30126	.95354	.31786	.94814	.33436	.94245	28
33	.26808	.96340	.28485	.95857	.30154	.95345	.31813	.94805	.33463	.94235	27
34	.26836	.96332	.28513	.95849	.30182	.95337	.31841	.94795	.33490	.94225	26
35	.26864	.96324	.28541	.95841	.30209	.95328	.31868	.94786	.33518	.94215	25
36	.26892	.96316	.28569	.95832	.30237	.95319	.31896	.94777	.33545	.94206	24
37	.26920	.96308	.28597	.95824	.30265	.95310	.31923	.94768	.33573	.94196	23
38	.26948	.96301	.28625	.95816	.30292	.95301	.31951	.94758	.33600	.94186	22
39	.26976	.96293	.28652	.95807	.30320	.95293	.31979	.94749	.33627	.94176	21
40	.27004	.96285	.28680	.95799	.30348	.95284	.32006	.94740	.33655	.94167	20
41	.27032	.96277	.28708	.95791	.30376	.95275	.32034	.94730	.33682	.94157	19
42	.27060	.96269	.28736	.95782	.30403	.95266	.32061	.94721	.33710	.94147	18
43	.27088	.96261	.28764	.95774	.30431	.95257	.32089	.94712	.33737	.94137	17
44	.27116	.96253	.28792	.95766	.30459	.95248	.32116	.94702	.33764	.94127	16
45	.27144	.96246	.28820	.95757	.30486	.95240	.32144	.94693	.33792	.94118	15
46	.27172	.96238	.28847	.95749	.30514	.95231	.32171	.94684	.33819	.94108	14
47	.27200	.96230	.28875	.95740	.30542	.95222	.32199	.94674	.33846	.94098	13
48	.27228	.96222	.28903	.95732	.30570	.95213	.32227	.94665	.33874	.94088	12
49	.27256	.96214	.28931	.95724	.30597	.95204	.32254	.94656	.33901	.94078	11
50	.27284	.96206	.28959	.95715	.30625	.95195	.32282	.94646	.33929	.94068	10
51	.27312	.96198	.28987	.95707	.30653	.95186	.32309	.94637	.33956	.94058	9
52	.27340	.96190	.29015	.95698	.30680	.95177	.32337	.94627	.33983	.94049	8
53	.27368	.96182	.29042	.95690	.30708	.95168	.32364	.94618	.34011	.94039	7
54	.27396	.96174	.29070	.95681	.30736	.95159	.32392	.94609	.34038	.94029	6
55	.27424	.96166	.29098	.95673	.30763	.95150	.32419	.94599	.34065	.94019	5
56	.27452	.96158	.29126	.95664	.30791	.95142	.32447	.94590	.34093	.94009	4
57	.27480	.96150	.29154	.95656	.30819	.95133	.32474	.94580	.34120	.93999	3
58	.27508	.96142	.29182	.95647	.30846	.95124	.32502	.94571	.34147	.93989	2
59	.27536	.96134	.29209	.95639	.30874	.95115	.32529	.94561	.34175	.93979	1
60	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	74°		73°		72°		71°		70°		

′	28°		29°		30°		31°	
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotan
0	.53171	1.88073	.55431	1.80405	.57735	1.73205	.60086	1.6642
1	.53208	1.87941	.55469	1.80281	.57774	1.73089	.60126	1.6631
2	.53246	1.87809	.55507	1.80158	.57813	1.72973	.60165	1.6620
3	.53283	1.87677	.55545	1.80034	.57851	1.72857	.60205	1.6609
4	.53320	1.87546	.55583	1.79911	.57890	1.72741	.60245	1.6599
5	.53358	1.87415	.55621	1.79788	.57929	1.72625	.60284	1.6588
6	.53395	1.87283	.55659	1.79665	.57968	1.72509	.60324	1.6577
7	.53432	1.87152	.55697	1.79542	.58007	1.72393	.60364	1.6566
8	.53470	1.87021	.55736	1.79419	.58046	1.72278	.60403	1.6555
9	.53507	1.86891	.55774	1.79296	.58085	1.72163	.60443	1.6544
10	.53545	1.86760	.55812	1.79174	.58124	1.72047	.60483	1.6533
11	.53582	1.86630	.55850	1.79051	.58162	1.71932	.60522	1.6522
12	.53620	1.86499	.55888	1.78929	.58201	1.71817	.60562	1.6512
13	.53657	1.86369	.55926	1.78807	.58240	1.71702	.60602	1.6501
14	.53694	1.86239	.55964	1.78685	.58279	1.71588	.60642	1.6490
15	.53732	1.86109	.56003	1.78563	.58318	1.71473	.60681	1.6479
16	.53769	1.85979	.56041	1.78441	.58357	1.71358	.60721	1.6468
17	.53807	1.85850	.56079	1.78319	.58396	1.71244	.60761	1.6457
18	.53844	1.85720	.56117	1.78198	.58435	1.71129	.60801	1.6447
19	.53882	1.85591	.56156	1.78077	.58474	1.71015	.60841	1.6436
20	.53920	1.85462	.56194	1.77955	.58513	1.70901	.60881	1.6425
21	.53957	1.85333	.56232	1.77834	.58552	1.70787	.60921	1.6414
22	.53995	1.85204	.56270	1.77713	.58591	1.70673	.60960	1.6404
23	.54032	1.85075	.56309	1.77592	.58631	1.70560	.61000	1.6393
24	.54070	1.84946	.56347	1.77471	.58670	1.70446	.61040	1.6382
25	.54107	1.84818	.56385	1.77351	.58709	1.70332	.61080	1.6371
26	.54145	1.84689	.56424	1.77230	.58748	1.70219	.61120	1.6361
27	.54183	1.84561	.56462	1.77110	.58787	1.70106	.61160	1.6350
28	.54220	1.84433	.56501	1.76990	.58826	1.69992	.61200	1.6339
29	.54258	1.84305	.56539	1.76869	.58865	1.69879	.61240	1.6329
30	.54296	1.84177	.56577	1.76749	.58905	1.69766	.61280	1.6318
31	.54333	1.84049	.56616	1.76629	.58944	1.69653	.61320	1.6307
32	.54371	1.83922	.56654	1.76510	.58983	1.69541	.61360	1.6297
33	.54409	1.83794	.56693	1.76390	.59022	1.69428	.61400	1.6286
34	.54446	1.83667	.56731	1.76271	.59061	1.69316	.61440	1.6276
35	.54484	1.83540	.56769	1.76151	.59101	1.69203	.61480	1.6265
36	.54522	1.83413	.56808	1.76032	.59140	1.69091	.61520	1.6254
37	.54560	1.83286	.56846	1.75913	.59179	1.68979	.61561	1.6244
38	.54597	1.83159	.56885	1.75794	.59218	1.68866	.61601	1.6233
39	.54635	1.83033	.56923	1.75675	.59258	1.68754	.61641	1.6223
40	.54673	1.82906	.56962	1.75556	.59297	1.68643	.61681	1.6212
41	.54711	1.82780	.57000	1.75437	.59336	1.68531	.61721	1.6201
42	.54748	1.82654	.57039	1.75319	.59376	1.68419	.61761	1.6191
43	.54786	1.82528	.57078	1.75200	.59415	1.68308	.61801	1.6180
44	.54824	1.82402	.57116	1.75082	.59454	1.68196	.61842	1.6170
45	.54862	1.82276	.57155	1.74964	.59494	1.68085	.61882	1.6159
46	.54900	1.82150	.57193	1.74846	.59533	1.67974	.61922	1.6149
47	.54938	1.82025	.57232	1.74728	.59573	1.67863	.61962	1.6138
48	.54975	1.81899	.57271	1.74610	.59612	1.67752	.62003	1.6128
49	.55013	1.81774	.57309	1.74492	.59651	1.67641	.62043	1.6117
50	.55051	1.81649	.57348	1.74375	.59691	1.67530	.62083	1.6107
51	.55089	1.81524	.57386	1.74257	.59730	1.67419	.62124	1.6097
52	.55127	1.81399	.57425	1.74140	.59770	1.67309	.62164	1.6086
53	.55165	1.81274	.57464	1.74022	.59809	1.67198	.62204	1.60761
54	.55203	1.81150	.57503	1.73905	.59849	1.67088	.62245	1.60657
55	.55241	1.81025	.57541	1.73788	.59888	1.66978	.62285	1.60553
56	.55279	1.80901	.57580	1.73671	.59928	1.66867	.62325	1.60449
57	.55317	1.80777	.57619	1.73555	.59967	1.66757	.62366	1.60345
58	.55355	1.80653	.57657	1.73438	.60007	1.66647	.62406	1.60241
59	.55393	1.80529	.57696	1.73321	.60046	1.66538	.62446	1.60137
60	.55431	1.80405	.57735	1.73205	.60086	1.66428	.62487	1.60033
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tan
	61°		60°		59°		58°	

′	32°		33°		34°		35°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	60
1	.62527	1.59930	.64982	1.53888	.67493	1.48163	.70064	1.42726	59
2	.62568	1.59826	.65024	1.53791	.67536	1.48070	.70107	1.42638	58
3	.62608	1.59723	.65065	1.53693	.67578	1.47977	.70151	1.42550	57
4	.62649	1.59620	.65106	1.53595	.67620	1.47885	.70194	1.42462	56
5	.62689	1.59517	.65148	1.53497	.67663	1.47792	.70238	1.42374	55
6	.62730	1.59414	.65189	1.53400	.67705	1.47699	.70281	1.42286	54
7	.62770	1.59311	.65231	1.53302	.67748	1.47607	.70325	1.42198	53
8	.62811	1.59208	.65272	1.53205	.67790	1.47514	.70368	1.42110	52
9	.62852	1.59105	.65314	1.53107	.67832	1.47422	.70412	1.42022	51
10	.62892	1.59002	.65355	1.53010	.67875	1.47330	.70455	1.41934	50
11	.62933	1.58900	.65397	1.52913	.67917	1.47238	.70499	1.41847	49
12	.62973	1.58797	.65438	1.52816	.67960	1.47146	.70542	1.41759	48
13	.63014	1.58695	.65480	1.52719	.68002	1.47053	.70586	1.41672	47
14	.63055	1.58593	.65521	1.52622	.68045	1.46962	.70629	1.41584	46
15	.63095	1.58490	.65563	1.52525	.68088	1.46870	.70673	1.41497	45
16	.63136	1.58388	.65604	1.52429	.68130	1.46778	.70717	1.41409	44
17	.63177	1.58286	.65646	1.52332	.68173	1.46686	.70760	1.41322	43
18	.63217	1.58184	.65688	1.52235	.68215	1.46595	.70804	1.41235	42
19	.63258	1.58083	.65729	1.52139	.68258	1.46503	.70848	1.41148	41
20	.63299	1.57981	.65771	1.52043	.68301	1.46411	.70891	1.41061	40
21	.63340	1.57879	.65813	1.51946	.68343	1.46320	.70935	1.40974	39
22	.63380	1.57778	.65854	1.51850	.68386	1.46229	.70979	1.40887	38
23	.63421	1.57676	.65896	1.51754	.68429	1.46137	.71023	1.40800	37
24	.63462	1.57575	.65938	1.51658	.68471	1.46046	.71066	1.40714	36
25	.63503	1.57474	.65980	1.51562	.68514	1.45955	.71110	1.40627	35
26	.63544	1.57372	.66021	1.51466	.68557	1.45864	.71154	1.40540	34
27	.63584	1.57271	.66063	1.51370	.68600	1.45773	.71198	1.40454	33
28	.63625	1.57170	.66105	1.51275	.68642	1.45682	.71242	1.40367	32
29	.63666	1.57069	.66147	1.51179	.68685	1.45592	.71285	1.40281	31
30	.63707	1.56969	.66189	1.51084	.68728	1.45501	.71329	1.40195	30
31	.63748	1.56868	.66230	1.50988	.68771	1.45410	.71373	1.40109	29
32	.63789	1.56767	.66272	1.50893	.68814	1.45320	.71417	1.40022	28
33	.63830	1.56667	.66314	1.50797	.68857	1.45229	.71461	1.39936	27
34	.63871	1.56566	.66356	1.50702	.68900	1.45139	.71505	1.39850	26
35	.63912	1.56466	.66398	1.50607	.68942	1.45049	.71549	1.39764	25
36	.63953	1.56366	.66440	1.50512	.68985	1.44958	.71593	1.39679	24
37	.63994	1.56265	.66482	1.50417	.69028	1.44868	.71637	1.39593	23
38	.64035	1.56165	.66524	1.50322	.69071	1.44778	.71681	1.39507	22
39	.64076	1.56065	.66566	1.50228	.69114	1.44688	.71725	1.39421	21
40	.64117	1.55966	.66608	1.50133	.69157	1.44598	.71769	1.39336	20
41	.64158	1.55866	.66650	1.50038	.69200	1.44508	.71813	1.39250	19
42	.64199	1.55766	.66692	1.49944	.69243	1.44418	.71857	1.39165	18
43	.64240	1.55666	.66734	1.49849	.69286	1.44329	.71901	1.39079	17
44	.64281	1.55567	.66776	1.49755	.69329	1.44239	.71946	1.38994	16
45	.64322	1.55467	.66818	1.49661	.69372	1.44149	.71990	1.38909	15
46	.64363	1.55368	.66860	1.49566	.69416	1.44060	.72034	1.38824	14
47	.64404	1.55269	.66902	1.49472	.69459	1.43970	.72078	1.38738	13
48	.64446	1.55170	.66944	1.49378	.69502	1.43881	.72122	1.38653	12
49	.64487	1.55071	.66986	1.49284	.69545	1.43792	.72167	1.38568	11
50	.64528	1.54972	.67028	1.49190	.69588	1.43703	.72211	1.38484	10
51	.64569	1.54873	.67071	1.49097	.69631	1.43614	.72255	1.38399	9
52	.64610	1.54774	.67113	1.49003	.69675	1.43525	.72299	1.38314	8
53	.64652	1.54675	.67155	1.48909	.69718	1.43436	.72344	1.38229	7
54	.64693	1.54576	.67197	1.48816	.69761	1.43347	.72388	1.38145	6
55	.64734	1.54478	.67239	1.48722	.69804	1.43258	.72432	1.38060	5
56	.64775	1.54379	.67282	1.48629	.69847	1.43169	.72477	1.37976	4
57	.64817	1.54281	.67324	1.48536	.69891	1.43080	.72521	1.37891	3
58	.64858	1.54183	.67366	1.48442	.69934	1.42992	.72565	1.37807	
59	.64899	1.54085	.67409	1.48349	.69977	1.42903	.72610	1.37722	
60	*.64941*	*1.53986*	.67451	1.48256	.70021	1.42815	.72654	1.3763	
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tan	
	57°		56°		55°		54°		

′	36°		37°		38°		39°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	60
1	.72699	1.37554	.75401	1.32624	.78175	1.27917	.81027	1.23416	59
2	.72743	1.37470	.75447	1.32544	.78222	1.27841	.81075	1.23343	58
3	.72788	1.37386	.75492	1.32464	.78269	1.27764	.81123	1.23270	57
4	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196	56
5	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123	55
6	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050	54
7	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977	53
8	.73010	1.36967	.75721	1.32064	.78504	1.27382	.81364	1.22904	52
9	.73055	1.36883	.75767	1.31984	.78551	1.27306	.81413	1.22831	51
10	.73100	1.36800	.75812	1.31904	.78598	1.27230	.81461	1.22758	50
11	.73144	1.36716	.75858	1.31825	.78645	1.27153	.81510	1.22685	49
12	.73189	1.36633	.75904	1.31745	.78692	1.27077	.81558	1.22612	48
13	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539	47
14	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467	46
15	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	45
16	.73368	1.36300	.76088	1.21427	.78881	1.26774	.81752	1.22321	44
17	.73413	1.36217	.76134	1.31348	.78928	1.26698	.81800	1.22249	43
18	.73457	1.36134	.76180	1.31269	.78975	1.26622	.81849	1.22176	42
19	.73502	1.36051	.76226	1.31190	.79022	1.26546	.81898	1.22104	41
20	.73547	1.35968	.76272	1.31110	.79070	1.26471	.81946	1.22031	40
21	.73592	1.35885	.76318	1.31031	.79117	1.26395	.81995	1.21959	39
22	.73637	1.35802	.76364	1.30952	.79164	1.26319	.82044	1.21886	38
23	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814	37
24	.73726	1.35637	.76456	1.30795	.79259	1.26169	.82141	1.21742	36
25	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670	35
26	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598	34
27	.73861	1.35389	.76594	1.30558	.79401	1.25943	.82287	1.21526	33
28	.73906	1.35307	.76640	1.30480	.79449	1.25867	.82336	1.21454	32
29	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382	31
30	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310	30
31	.74041	1.35060	.76779	1.30244	.79591	1.25642	.82483	1.21238	29
32	.74086	1.34978	.76825	1.30166	.79639	1.25567	.82531	1.21166	28
33	.74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	27
34	.74176	1.34814	.76918	1.30009	.79734	1.25417	.82629	1.21023	26
35	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951	25
36	.74267	1.34650	.77010	1.29853	.79829	1.25268	.82727	1.20879	24
37	.74312	1.34568	.77057	1.29775	.79877	1.25193	.82776	1.20808	23
38	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736	22
39	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665	21
40	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593	20
41	74492	1.34242	.77242	1.29463	.80067	1.24895	.82972	1.20522	19
42	.74538	1.34160	.77289	1.29385	.80115	1.24820	.83022	1.20451	18
43	.74583	1.34079	.77335	1.29307	.80163	1.24746	.83071	1.20379	17
44	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1.20308	16
45	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237	15
46	.74719	1.33835	.77475	1.29074	.80306	1.24523	.83218	1.20166	14
47	.74764	1.33754	.77521	1.28997	.80354	1.24449	.83268	1.20095	13
48	.74810	1.33673	.77568	1.28919	.80402	1.24375	.83317	1.20024	12
49	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953	11
50	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	10
51	.74946	1.33430	.77708	1.28687	.80546	1.24153	.83465	1.19811	9
52	.74991	1.33349	.77754	1.28610	.80594	1.24079	.83514	1.19740	8
53	.75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669	7
54	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599	6
55	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	5
56	.75173	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457	4
57	.75219	1.32946	.77988	1.28225	.80834	1.23710	.83761	1.19387	3
58	.75264	1.32865	.78035	1.28148	.80882	1.23637	.83811	1.19316	2
59	.75310	1.32785	.78082	1.28071	.80930	1.23563	.83860	1.19246	1
60	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
	°		52°		51°		50°		

′	40°		41°		42°		43°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	53
8	.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	33
28	.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	14
47	.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	
59	.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	
60	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.0355	
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Ta	
	49°		48°		47°				

′	44°		′	′	44°		′	′	44°		′
	Tang	Cotang			Tang	Cotang			Tang	Cotang	
0	.96569	1.03553	60	20	.97700	1.02355	40	40	.98843	1.01170	20
1	.96625	1.03493	59	21	.97756	1.02295	39	41	.98901	1.01112	19
2	.96681	1.03433	58	22	.97813	1.02236	38	42	.98958	1.01053	18
3	.96738	1.03372	57	23	.97870	1.02176	37	43	.99016	1.00994	17
4	.96794	1.03312	56	24	.97927	1.02117	36	44	.99073	1.00935	16
5	.96850	1.03252	55	25	.97984	1.02057	35	45	.99131	1.00876	15
6	.96907	1.03192	54	26	.98041	1.01998	34	46	.99189	1.00818	14
7	.96963	1.03132	53	27	.98098	1.01939	33	47	.99247	1.00759	13
8	.97020	1.03072	52	28	.98155	1.01879	32	48	.99304	1.00701	12
9	.97076	1.03012	51	29	.98213	1.01820	31	49	.99362	1.00642	11
10	.97133	1.02952	50	30	.98270	1.01761	30	50	.99420	1.00583	10
11	.97189	1.02892	49	31	.98327	1.01702	29	51	.99478	1.00525	9
12	.97246	1.02832	48	32	.98384	1.01642	28	52	.99536	1.00467	8
13	.97302	1.02772	47	33	.98441	1.01583	27	53	.99594	1.00408	7
14	.97359	1.02713	46	34	.98499	1.01524	26	54	.99652	1.00350	6
15	.97416	1.02653	45	35	.98556	1.01465	25	55	.99710	1.00291	5
16	.97472	1.02593	44	36	.98613	1.01406	24	56	.99768	1.00233	4
17	.97529	1.02533	43	37	.98671	1.01347	23	57	.99826	1.00175	3
18	.97586	1.02474	42	38	.98728	1.01288	22	58	.99884	1.00116	2
19	.97643	1.02414	41	39	.98786	1.01229	21	59	.99942	1.00058	1
20	.97700	1.02355	40	40	.98843	1.01170	20	60	1.00000	1.00000	0
′	Cotang	Tang	′	′	Cotang	Tang	′	′	Cotang	Tang	′
	45°				45°				45°		

VERSINE FOR ANGLES BEYOND 90 DEGREES.

In Tables XXVI and XXIX the values of log versine and nat versine are extended to 90°.

When the given angle A is greater than 90°, make the following substitution:

$$\log \operatorname{vers} A = \log 2 \sin^2 \tfrac{1}{2}A,$$

or

$$\operatorname{vers} A = 1 + \sin (A - 90°).$$

Whatever be the value of A, vers A is always positive.

The exsecant of the supplement of an angle is the same as exsecant of the angle itself but with a change of sign: thus,

$$\operatorname{exsec} A = - \operatorname{exsec} (180° - A).$$

′	0°		1°		2°		3°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.00000	.00000	.00015	.00015	.00061	.00061	.00137	.00137	0
1	.00000	.00000	.00016	.00016	.00062	.00062	.00139	00139	1
2	.00000	.00000	.00016	.00016	.00063	.00063	.00140	.00140	2
3	.00000	.00000	.00017	.00017	.00064	.00064	.00142	.00142	3
4	.00000	.00000	.00017	.00017	.00065	.00065	.00143	.00143	4
5	.00000	.00000	.00018	.00018	.00066	.00066	.00145	.00145	5
6	.00000	.00000	.00018	.00018	.00067	.00067	.00146	.00147	6
7	.00000	.00000	.00019	.00019	.00068	.00068	.00148	.00148	7
8	.00000	.00000	.00020	.00020	.00069	.00069	.00150	.00150	8
9	.00000	.00000	.00020	.00020	.00070	.00070	.00151	.00151	9
10	.00000	.00000	.00021	.00021	.00071	.00072	.00153	.00153	10
11	.00001	.00001	.00021	.00021	.00073	.00073	.00154	.00155	11
12	.00001	.00001	.00022	.00022	.00074	.00074	.00156	.00156	12
13	.00001	.00001	.00023	.00023	.00075	.00075	.00158	.00158	13
14	.00001	.00001	.00023	.00023	.00076	.00076	.00159	.00159	14
15	.00001	.00001	.00024	.00024	.00077	.00077	.00161	.00161	15
16	.00001	.00001	.00024	.00024	.00078	.00078	.00162	.00163	16
17	.00001	.00001	.00025	.00025	.00079	.00079	.00164	.00164	17
18	.00001	.00001	.00026	.00026	.00081	.00081	.00166	.00166	18
19	.00002	.00002	.00026	.00026	.00082	.00082	.00168	.00168	19
20	.00002	.00002	.00027	.00027	.00083	.00083	.00169	.00169	20
21	.00002	.00002	.00028	.00028	.00084	.00084	.00171	.00171	21
22	.00002	.00002	.00028	.00028	.00085	.00085	.00173	.00173	22
23	.00002	.00002	.00029	.00029	.00087	.00087	.00174	.00175	23
24	.00002	.00002	.00030	.00030	.00088	.00088	.00176	.00176	24
25	.00003	.00003	.00031	.00031	.00089	.00089	.00178	.00178	25
26	.00003	.00003	.00031	.00031	.00090	.00090	.00179	.00180	26
27	.00003	.00003	.00032	.00032	.00091	.00091	.00181	.00182	27
28	.00003	.00003	.00033	.00033	.00093	.00093	.00183	.00183	28
29	.00004	.00004	.00034	.00034	.00094	.00094	.00185	.00185	29
30	.00004	.00004	.00034	.00034	.00095	.00095	.00187	.00187	30
31	.00004	.00004	.00035	.00035	.00096	.00097	.00188	.00189	31
32	.00004	.00004	.00036	.00036	.00098	.00098	.00190	.00190	32
33	.00005	.00005	.00037	.00037	.00099	.00099	.00192	.00192	33
34	.00005	.00005	.00037	.00037	.00100	.00100	.00194	.00194	34
35	.00005	00005	.00038	.00038	.00102	.00102	.00196	.00196	35
36	00005	.00005	.00039	.00039	.00103	.00103	.00197	00198	36
37	00006	.00006	.00040	.00040	.00104	.00104	.00199	.00200	37
38	.00006	.00006	.00041	.00041	.00106	.00106	00201	.00201	38
39	.00006	.00006	.00041	.00041	.00107	.00107	.00203	00203	39
40	.00007	.00007	.00042	.00042	.00108	.00108	.00205	00205	40
41	.00007	.00007	.00043	.00043	.00110	.00110	.00207	.00207	41
42	.00007	.00007	.00044	.00044	.00111	.00111	.00208	.00209	42
43	.00008	.00008	.00045	.00045	.00112	.00113	.00210	.00211	43
44	.00008	.00008	.00046	.00046	.00114	.00114	.00212	.00213	44
45	.00009	.00009	.00047	.00047	.00115	.00115	.00214	.00215	45
46	.00009	.00009	.00048	.00048	.00117	.00117	.00216	.00216	46
47	.00009	.00009	.00048	.00048	.00118	.00118	.00218	.00218	47
48	.00010	.00010	.00049	.00049	.00119	.00120	.00220	.00220	48
49	.00010	.00010	.00050	.00050	.00121	.00121	.00222	.00222	49
50	.00011	.00011	.00051	.00051	.00122	.00122	.00224	.00224	50
51	.00011	.00011	.00052	.00052	.00124	.00124	.00226	.00226	51
52	.00011	.00011	.00053	.00053	.00125	.00125	.00228	.00228	52
53	.00012	.00012	.00054	.00054	.00127	.00127	.00230	.00230	53
54	.00012	.00012	.00055	.00055	.00128	.00128	.00232	.00232	54
55	.00013	.00013	.00056	.00056	.00130	.00130	.00234	.00234	55
56	.00013	.00013	.00057	.00057	.00131	.00131	.00236	.00236	
57	.00014	.00014	.00058	.00058	.00133	.00133	.00238	.00238	
58	.00014	00014	.00059	.00059	.00134	.00134	.00240	.00240	
59	.00015	.00015	.00060	.00060	.00136	.00136	.00242		
60	.00015	.00015	.00061	.00061	.00137	.00137	.00244		

′	4°		5°		6°		7°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.00244	.00244	.00381	.00382	.00548	.00551	.00745	.00751	0
1	.00246	.00246	.00383	.00385	.00551	.00554	.00749	.00755	1
2	.00248	.00248	.00386	.00387	.00554	.00557	.00752	.00758	2
3	.00250	.00250	.00388	.00390	.00557	.00560	.00756	.00762	3
4	.00252	.00252	.00391	.00392	.00560	.00563	.00760	.00765	4
5	.00254	.00254	.00393	.00395	.00563	.00566	.00763	.00769	5
6	.00256	.00257	.00396	.00397	.00566	.00569	.00767	.00773	6
7	.00258	.00259	.00398	.00400	.00569	.00573	.00770	.00776	7
8	.00260	.00261	.00401	.00403	.00572	.00576	.00774	.00780	8
9	.00262	.00263	.00404	.00405	.00576	.00579	.00778	.00784	9
10	.00264	.00265	.00406	.00408	.00579	.00582	.00781	.00787	10
11	.00266	.00267	.00409	.00411	.00582	.00585	.00785	.00791	11
12	.00269	.00269	.00412	.00413	.00585	.00588	.00789	.00795	12
13	.00271	.00271	.00414	.00416	.00588	.00592	.00792	.00799	13
14	.00273	.00274	.00417	.00419	.00591	.00595	.00796	.00802	14
15	.00275	.00276	.00420	.00421	.00594	.00598	.00800	.00806	15
16	.00277	.00278	.00422	.00424	.00598	.00601	.00803	.00810	16
17	.00279	.00280	.00425	.00427	.00601	.00604	.00807	.00813	17
18	.00281	.00282	.00428	.00429	.00604	.00608	.00811	.00817	18
19	.00284	.00284	.00430	.00432	.00607	.00611	.00814	.00821	19
20	.00286	.00287	.00433	.00435	.00610	.00614	.00818	.00825	20
21	.00288	.00289	.00436	.00438	.00614	.00617	.00822	.00828	21
22	.00290	.00291	.00438	.00440	.00617	.00621	.00825	.00832	22
23	.00293	.00293	.00441	.00443	.00620	.00624	.00829	.00836	23
24	.00295	.00296	.00444	.00446	.00623	.00627	.00833	.00840	24
25	.00297	.00298	.00447	.00449	.00626	.00630	.00837	.00844	25
26	.00299	.00300	.00449	.00451	.00630	.00634	.00840	.00848	26
27	.00301	.00302	.00452	.00454	.00633	.00637	.00844	.00851	27
28	.00304	.00305	.00455	.00457	.00636	.00640	.00848	.00855	28
29	.00306	.00307	.00458	.00460	.00640	.00644	.00852	.00859	29
30	.00308	.00309	.00460	.00463	.00643	.00647	.00856	.00863	30
31	.00311	.00312	.00463	.00465	.00646	.00650	.00859	.00867	31
32	.00313	.00314	.00466	.00468	.00649	.00654	.00863	.00871	32
33	.00315	.00316	.00469	.00471	.00653	.00657	.00867	.00875	33
34	.00317	.00318	.00472	.00474	.00656	.00660	.00871	.00878	34
35	.00320	.00321	.00474	.00477	.00659	.00664	.00875	.00882	35
36	.00322	.00323	.00477	.00480	.00663	.00667	.00878	.00886	36
37	.00324	.00326	.00480	.00482	.00666	.00671	.00882	.00890	37
38	.00327	.00328	.00483	.00485	.00669	.00674	.00886	.00894	38
39	.00329	.00330	.00486	.00488	.00673	.00677	.00890	.00898	39
40	.00332	.00333	.00489	.00491	.00676	.00681	.00894	.00902	40
41	.00334	.00335	.00492	.00494	.00680	.00684	.00898	.00906	41
42	.00336	.00337	.00494	.00497	.00683	.00688	.00902	.00910	42
43	.00339	.00340	.00497	.00500	.00686	.00691	.00906	.00914	43
44	.00341	.00342	.00500	.00503	.00690	.00695	.00909	.00918	44
45	.00343	.00345	.00503	.00506	.00693	.00698	.00913	.00922	45
46	.00346	.00347	.00506	.00509	.00697	.00701	.00917	.00926	46
47	.00348	.00350	.00509	.00512	.00700	.00705	.00921	.00930	47
48	.00351	.00352	.00512	.00515	.00703	.00708	.00925	.00934	48
49	.00353	.00354	.00515	.00518	.00707	.00712	.00929	.00938	49
50	.00356	.00357	.00518	.00521	.00710	.00715	.00933	.00942	50
51	.00358	.00359	.00521	.00524	.00714	.00719	.00937	.00946	51
52	.00361	.00362	.00524	.00527	.00717	.00722	.00941	.00950	52
53	.00363	.00364	.00527	.00530	.00721	.00726	.00945	.00954	53
54	.00365	.00367	.00530	.00533	.00724	.00730	.00949	.00958	54
55	.00368	.00369	.00533	.00536	.00728	.00733	.00953	.00962	55
56	.00370	.00372	.00536	.00539	.00731	.00737	.00957	.00966	56
[illegible]	.00373	.00374	.00539	.00542	.00735	.00740	.00961	.00970	57
[illegible]	.00375	.00377	.00542	.00545	.00738	.00744	.00965	.00975	58
[illegible]	[illegible]	.00379	.00545	.00548	.00742	.00747	.00969	.00979	59
[illegible]	[illegible]	.00382	.00548	.00551	.00745	.00751	.00973	.00983	6

′	8°		9°		10°		11°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.00973	.00983	.01231	.01247	.01519	.01543	.01837	.01872	0
1	.00977	.00987	.01236	.01251	.01524	.01548	.01843	.01877	1
2	.00981	.00991	.01240	.01256	.01529	.01553	.01848	.01883	2
3	.00985	.00995	.01245	.01261	.01534	.01558	.01854	.01889	3
4	.00989	.00999	.01249	.01265	.01540	.01564	.01860	.01895	4
5	.00994	.01004	.01254	.01270	.01545	.01569	.01865	.01901	5
6	.00998	.01008	.01259	.01275	.01550	.01574	.01871	.01906	6
7	.01002	.01012	.01263	.01279	.01555	.01579	.01876	.01912	7
8	.01006	.01016	.01268	.01284	.01560	.01585	.01882	.01918	8
9	.01010	.01020	.01272	.01289	.01565	.01590	.01888	.01924	9
10	.01014	.01024	.01277	.01294	.01570	.01595	.01893	.01930	10
11	.01018	.01029	.01282	.01298	.01575	.01601	.01899	.01936	11
12	.01022	.01033	.01286	.01303	.01580	.01606	.01904	.01941	12
13	.01027	.01037	.01291	.01308	.01586	.01611	.01910	.01947	13
14	.01031	.01041	.01296	.01313	.01591	.01616	.01916	.01953	14
15	.01035	.01046	.01300	.01318	.01596	.01622	.01921	.01959	15
16	.01039	.01050	.01305	.01322	.01601	.01627	.01927	.01965	16
17	.01043	.01054	.01310	.01327	.01606	.01633	.01933	.01971	17
18	.01047	.01059	.01314	.01332	.01612	.01638	.01939	.01977	18
19	.01052	.01063	.01319	.01337	.01617	.01643	.01944	.01983	19
20	.01056	.01067	.01324	.01342	.01622	.01649	.01950	.01989	20
21	.01060	.01071	.01329	.01346	.01627	.01654	.01956	.01995	21
22	.01064	.01076	.01333	.01351	.01632	.01659	.01961	.02001	22
23	.01069	.01080	.01338	.01356	.01638	.01665	.01967	.02007	23
24	.01073	.01084	.01343	.01361	.01643	.01670	.01973	.02013	24
25	.01077	.01089	.01348	.01366	.01648	.01676	.01979	.02019	25
26	.01081	.01093	.01352	.01371	.01653	.01681	.01984	.02025	26
27	.01086	.01097	.01357	.01376	.01659	.01687	.01990	.02031	27
28	.01090	.01102	.01362	.01381	.01664	.01692	.01996	.02037	28
29	.01094	.01106	.01367	.01386	.01669	.01698	.02002	.02043	29
30	.01098	.01111	.01371	.01391	.01675	.01703	.02008	.02049	30
31	.01103	.01115	.01376	.01395	.01680	.01709	.02013	.02055	31
32	.01107	.01119	.01381	.01400	.01685	.01714	.02019	.02061	32
33	.01111	.01124	.01386	.01405	.01690	.01720	.02025	.02067	33
34	.01116	.01128	.01391	.01410	.01696	.01725	.02031	.02073	34
35	.01120	.01133	.01396	.01415	.01701	.01731	.02037	.02079	35
36	.01124	.01137	.01400	.01420	.01706	.01736	.02042	.02085	36
37	.01129	.01142	.01405	.01425	.01712	.01742	.02048	.02091	37
38	.01133	.01146	.01410	.01430	.01717	.01747	.02054	.02097	38
39	.01137	.01151	.01415	.01435	.01723	.01753	.02060	.02103	39
40	.01142	.01155	.01420	.01440	.01728	.01758	.02066	.02110	40
41	.01146	.01160	.01425	.01445	.01733	.01764	.02072	.02116	41
42	.01151	.01164	.01430	.01450	.01739	.01769	.02078	.02122	42
43	.01155	.01169	.01435	.01455	.01744	.01775	.02084	.02128	43
44	.01159	.01173	.01439	.01461	.01750	.01781	.02090	.02134	44
45	.01164	.01178	.01444	.01466	.01755	.01786	.02095	.02140	45
46	.01168	.01182	.01449	.01471	.01760	.01792	.02101	.02146	46
47	.01173	.01187	.01454	.01476	.01766	.01798	.02107	.02153	47
48	.01177	.01191	.01459	.01481	.01771	.01803	.02113	.02159	48
49	.01182	.01196	.01464	.01486	.01777	.01809	.02119	.02165	49
50	.01186	.01200	.01469	.01491	.01782	.01815	.02125	.02171	50
51	.01191	.01205	.01474	.01496	.01788	.01820	.02131	.02178	51
52	.01195	.01209	.01479	.01501	.01793	.01826	.02137	.02184	52
53	.01200	.01214	.01484	.01506	.01799	.01832	.02143	.02190	53
54	.01204	.01219	.01489	.01512	.01804	.01837	.02149	.02196	54
55	.01209	.01223	.01494	.01517	.01810	.01843	.02155	.02203	55
56	*.01213*	*.01228*	*.01499*	.01522	.01815	.01849	.02161	.02209	56
57	*.01218*	*.01233*	*.01504*	.01527	.01821	.01854	.02167	.02215	
58	*.01222*	*.01237*	*.01509*	.01532	.01826	.01860	.02173	.02221	
59	*.01227*	*.01242*	*.01514*	.01537	.01832	.01866	.02179	[illegible]	
60	*.01231*	*.01247*	*.01519*	.01543	.01837	.01872	.02185	[illegible]	

′	12°		13°		14°		15°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.02185	.02234	.02563	.02630	.02970	.03061	.03407	.03528	0
1	.02191	.02240	.02570	.02637	.02977	.03069	.03415	.03536	1
2	.02197	.02247	.02576	.02644	.02985	.03076	.03422	.03544	2
3	.02203	.02253	.02583	.02651	.02992	.03084	.03430	.03552	3
4	.02210	.02259	.02589	.02658	.02999	.03091	.03438	.03560	4
5	.02216	.02266	.02596	.02665	.03006	.03099	.03445	.03568	5
6	.02222	.02272	.02602	.02672	.03013	.03106	.03453	.03576	6
7	.02228	.02279	.02609	.02679	.03020	.03114	.03460	.03584	7
3	.02234	.02285	.02616	.02686	.03027	.03121	.03468	.03592	8
9	.02240	.02291	.02622	.02693	.03034	.03129	.03476	.03601	9
10	.02246	.02298	.02629	.02700	.03041	.03137	.03483	.03609	10
11	.02252	.02304	.02635	.02707	.03048	.03144	.03491	.03617	11
12	.02258	.02311	.02642	.02714	.03055	.03152	.03498	.03625	12
13	.02265	.02317	.02649	.02721	.03063	.03159	.03506	.03633	13
14	.02271	.02323	.02655	.02728	.03070	.03167	.03514	.03642	14
15	.02277	.02330	.02662	.02735	.03077	.03175	.03521	.03650	15
16	.02283	.02336	.02669	.02742	.03084	.03182	.03529	.03658	16
17	.02289	.02343	.02675	.02749	.03091	.03190	.03537	.03666	17
18	.02295	.02349	.02682	.02756	.03098	.03198	.03544	.03674	18
19	.02302	.02356	.02689	.02763	.03106	.03205	.03552	.03683	19
20	.02308	.02362	.02696	.02770	.03113	.03213	.03560	.03691	20
21	.02314	.02369	.02702	.02777	.03120	.03221	.03567	.03699	21
22	.02320	.02375	.02709	.02784	.03127	.03228	.03575	.03708	22
23	.02327	.02382	.02716	.02791	.03134	.03236	.03583	.03716	23
24	.02333	.02388	.02722	.02799	.03142	.03244	.03590	.03724	24
25	.02339	.02395	.02729	.02806	.03149	.03251	.03598	.03732	25
26	.02345	.02402	.02736	.02813	.03156	.03259	.03606	.03741	26
27	.02352	.02408	.02743	.02820	.03163	.03267	.03614	.03749	27
28	.02358	.02415	.02749	.02827	.03171	.03275	.03621	.03758	28
29	.02364	.02421	.02756	.02834	.03178	.03282	.03629	.03766	29
30	.02370	.02428	.02763	.02842	.03185	.03290	.03637	.03774	30
31	.02377	.02435	.02770	.02849	.03193	.03298	.03645	.03783	31
32	.02383	.02441	.02777	.02856	.03200	.03306	.03653	.03791	32
33	.02389	.02448	.02783	.02863	.03207	.03313	.03660	.03799	33
34	.02396	.02454	.02790	.02870	.03214	.03321	.03668	.03808	34
35	.02402	.02461	.02797	.02878	.03222	.03329	.03676	.03816	35
36	.02408	.02468	.02804	.02885	.03229	.03337	.03684	.03825	36
37	.02415	.02474	.02811	.02892	.03236	.03345	.03692	.03833	37
38	.02421	.02481	.02818	.02899	.03244	.03353	.03699	.03842	38
39	.02427	.02488	.02824	.02907	.03251	.03360	.03707	.03850	39
40	.02434	.02494	.02831	.02914	.03258	.03368	.03715	.03858	40
41	.02440	.02501	.02838	.02921	.03266	.03376	.03723	.03867	41
42	.02417	.02508	.02845	.02928	.03273	.03384	.03731	.03875	42
43	.02453	.02515	.02852	.02936	.03281	.03392	.03739	.03884	43
44	.02459	.02521	.02859	.02943	.03288	.03400	.03747	.03892	44
45	.02466	.02528	.02866	.02950	.03295	.03408	.03754	.03901	45
46	.02472	.02535	.02873	.02958	.03303	.03416	.03762	.03909	46
47	.02479	.02542	.02880	.02965	.03310	.03424	.03770	.03918	47
48	.02485	.02548	.02887	.02972	.03318	.03432	.03778	.03927	48
49	.02492	.02555	.02894	.02980	.03325	.03439	.03786	.03935	49
50	.02498	.02562	.02900	.02987	.03333	.03447	.03794	.03944	50
51	.02504	.02569	.02907	.02994	.03340	.03455	.03802	.03952	51
52	.02511	.02576	.02914	.03002	.03347	.03463	.03810	.03961	52
53	.02517	.02582	.02921	.03009	.03355	.03471	.03818	.03969	53
54	.02524	.02589	.02928	.03017	.03362	.03479	.03826	.03978	54
55	.02530	.02596	.02935	.03024	.03370	.03187	.03834	.03987	55
56	.02537	.02603	.02942	.03032	.03377	.03495	.03842	.03995	56
	.02543	.02610	.02949	.03039	.03385	.03503	.03850	.04004	57
	.02550	.02617	.02956	.03046	.03392	.03512	.03858	.04013	58
	.02556	.02624	.02963	.03054	.03400	.03520	.03866	.04021	
	3	.02630	.02970	.03061	.03407	.03528	.03874	.04030	

′	16°		17°		18°		19°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.03874	.04030	.04370	.04569	.04894	.05146	.05448	.05762	0
1	.03882	.04039	.04378	.04578	.04903	.05156	.05458	.05773	1
2	.03890	.04047	.04387	.04588	.04912	.05166	.05467	.05783	2
3	.03898	.04056	.04395	.04597	.04921	.05176	.05477	.05794	3
4	.03906	.04065	.04404	.04606	.04930	.05186	.05486	.05805	4
5	.03914	.04073	.04412	.04616	.04939	.05196	.05496	.05815	5
6	.03922	.04082	.04421	.04625	.04948	.05206	.05505	.05826	6
7	.03930	.04091	.04429	.04635	.04957	.05216	.05515	.05836	7
8	.03938	.04100	.04438	.04644	.04967	.05226	.05524	.05847	8
9	.03946	.04108	.04446	.04653	.04976	.05236	.05534	.05858	9
10	.03954	.04117	.04455	.04663	.04985	.05246	.05543	.05869	10
11	.03963	.04126	.04464	.04672	.04994	.05256	.05553	.05879	11
12	.03971	.04135	.04472	.04683	.05003	.05266	.05562	.05890	12
13	.03979	.04144	.04481	.04691	.05012	.05276	.05572	.05901	13
14	.03987	.04152	.04489	.04700	.05021	.05286	.05582	.05911	14
15	.03995	.04161	.04498	.04710	.05030	.05297	.05591	.05922	15
16	.04003	.04170	.04507	.04719	.05039	.05307	.05601	.05933	16
17	.04011	.04179	.04515	.04729	.05048	.05317	.05610	.05944	17
18	.04019	.04188	.04524	.04738	.05057	.05327	.05620	.05955	18
19	.04028	.04197	.04533	.04748	.05067	.05337	.05630	.05965	19
20	.04036	.04206	.04541	.04757	.05076	.05347	.05639	.05976	20
21	.04044	.04214	.04550	.04767	.05085	.05357	.05649	05987	21
22	.04052	.04223	.04559	.04776	.05094	.05367	.05658	.05998	22
23	.04060	.04232	.04567	.04786	.05103	.05378	.05668	.06009	23
24	.04069	.04241	.04576	.04795	.05112	.05388	.05678	.06020	24
25	.04077	.04250	.04585	.04805	.05122	.05398	.05687	.06030	25
26	.04085	.04259	.04593	.04815	.05131	.05408	.05697	.06041	26
27	.04093	.04268	.04602	.04824	.05140	.05418	.05707	.06052	27
28	.04102	.04277	.04611	.04834	.05149	.05429	.05716	.06063	28
29	.04110	.04286	.04620	.04843	.05158	.05439	.05726	.06074	29
30	.04118	.04295	.04628	.04853	.05168	.05449	.05736	.06085	30
31	.04126	.04304	.04637	.04863	.05177	.05460	.05746	.00096	31
32	.04135	.04313	.04646	.04872	.05186	.05470	.05755	.06107	32
33	.04143	.04322	.04655	.04882	.05195	.05480	.05765	.06118	33
34	.04151	.04331	.04663	.04891	.05205	.05490	.05775	.06129	34
35	.04159	.04340	.04672	.04901	.05214	.05501	.05785	.06140	35
36	.04168	.04349	.04681	.04911	.05223	.05511	.05794	.06151	36
37	.04176	.04358	.04690	04920	.05232	.05521	.05804	.06162	37
38	.04184	.04367	.04699	.04930	.05242	.05532	.05814	.06173	38
39	.04193	.04376	.04707	.04940	.05251	.05542	.05824	.06184	39
40	.04201	.04385	.04716	.04950	.05260	.05552	.05833	.06195	40
41	.04209	.04394	.04725	.04959	.05270	.05563	.05843	.00206	41
42	.04218	.04403	.04734	.04969	.05279	.05573	.05853	.06217	42
43	.04226	.04413	.04743	.04979	.05288	.05584	.05863	.06228	43
44	.04234	.04422	.04752	.04989	.05298	.05594	.05873	.06239	44
45	.04243	.04431	.04760	.04998	.05307	.05604	.05882	.06250	45
46	.04251	.04440	.04769	.05008	.05316	.05615	.05892	.06261	46
47	.04260	.04449	.04778	.05018	.05326	.05625	.05902	.06272	47
48	.04268	.04458	.04787	.05028	.05335	.05636	.05912	.06283	48
49	.04276	.04468	04796	.05038	.05344	.05646	.05922	.06295	49
50	.04285	.04477	.04805	.05047	.05354	.05657	.05932	.06306	50
51	.04293	.04486	.04814	.05057	.05363	.05667	.05942	.06317	51
52	.04302	.04495	.04823	.05067	.05373	.05678	.05951	.06328	52
53	.04310	.04504	.04832	.05077	.05382	.05688	05961	.06339	53
54	.04319	.04514	.04841	.05087	.05391	.05699	.05971	.06350	54
55	.04327	.04523	.04850	.05097	.05401	.05709	.05981	.06362	55
56	.04336	.04532	.04858	.05107	.05410	.05720	.05991	.06373	56
57	.04344	.04541	.04867	.05116	.05420	.05730	.06001	.06384	[illegible]
58	.04353	.04551	.04876	.05126	.05429	.05741	.06011	.06395	[illegible]
59	.04361	.04560	.04885	.05136	.05439	.05751	.06021	.06407	[illegible]
60	.04370	.04569	.04894	.05146	.05448	.05762	.06031	[illegible]	[illegible]

′	20°		21°		22°		23°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.06031	.06418	.06642	.07115	.07282	.07853	.07950	.08636	0
1	.06041	.06429	.06652	.07126	.07293	.07866	.07961	.08649	1
2	.06051	.06440	.06663	.07138	.07303	.07879	.07972	.08663	2
3	.06061	.06452	.06673	.07150	.07314	.07892	.07984	08676	3
4	.06071	.06463	.06684	.07162	.07325	.07904	.07995	.08690	4
5	.06081	.06474	.06694	.07174	.07336	.07917	.08006	.08703	5
6	.06091	.06486	.06705	.07186	.07347	.07930	.08018	.08717	6
7	.06101	.06497	.06715	.07199	.07358	.07943	.08029	.08730	7
8	.06111	.06508	.06726	.07211	.07369	.07955	.08041	.08744	8
9	.06121	.06520	.06736	.07223	.07380	.07968	.08052	.08757	9
10	.06131	.06531	.06747	.07235	.07391	.07981	.08064	.08771	10
11	.06141	.06542	.06757	.07247	.07402	.07994	.08075	.08784	11
12	.06151	.06554	.06768	.07259	.07413	.08006	.08086	.08798	12
13	.06161	.06565	.06778	.07271	.07424	.08019	.08098	.08811	13
14	.06171	.06577	.06789	.07283	.07435	.08032	.08109	.08825	14
15	.06181	.06588	.06799	.07295	.07446	.08045	.08121	.08839	15
16	.06191	.06600	.06810	.07307	.07457	.08058	.08132	.08852	16
17	.06201	.06611	.06820	.07320	.07468	.08071	.08144	.08866	17
18	.06211	.06622	.06831	.07332	.07479	.08084	.08155	.08880	18
19	.06221	.06634	.06841	.07344	.07490	.08097	.08167	.08893	19
20	.06231	.06645	.06852	.07356	.07501	.08109	.08178	.08907	20
21	.06241	.06657	.06863	.07368	.07512	.08122	.08190	.08921	21
22	.06252	.06668	.06873	.07380	.07523	.08135	.08201	.08934	22
23	.06262	.06680	.06884	.07393	.07534	.08148	.08213	.08948	23
24	.06272	.06691	.06894	.07405	.07545	.08161	.08225	.08962	24
25	.06282	.06703	.06905	.07417	.07556	.08174	.08236	.08975	25
26	.06292	.06715	.06916	.07429	.07568	.08187	.08248	.08989	26
27	.06302	.06726	.06926	.07442	.07579	.08200	.08259	.09003	27
28	.06312	.06738	.06937	.07454	.07590	.08213	.08271	.09017	28
29	.06323	.06749	.06948	.07466	.07601	.08226	.08282	.09030	29
30	.06333	.06761	.06958	.07479	.07612	.08239	.08294	.09044	30
31	.06343	.06773	.06969	.07491	.07623	.08252	.08306	.09058	31
32	.06353	.06784	.06980	.07503	.07634	.08265	.08317	.09072	32
33	.06363	.06796	.06990	.07516	.07645	.08278	.08329	.09086	33
34	.06374	.06807	.07001	.07528	.07657	.08291	.08340	.09099	34
35	.06384	.06819	.07012	.07540	.07668	.08305	.08352	.09113	35
36	.06394	.06831	.07022	.07553	.07679	.08318	.08364	.09127	36
37	.06404	.06843	.07033	.07565	.07690	.08331	.08375	.09141	37
38	.06415	.06854	.07044	.07578	.07701	.08344	.08387	.09155	38
39	.06425	.06866	.07055	.07590	.07713	.08357	.08399	.09169	39
40	.06435	.06878	.07065	.07602	.07724	.08370	.08410	.09183	40
41	.06445	.06889	.07076	.07615	.07735	.08383	.08422	.09197	41
42	.06456	.06901	.07087	.07627	.07746	.08397	.08434	.09211	42
43	.06466	.06913	.07098	.07640	.07757	.08410	.08445	.09224	43
44	.06476	.06925	.07108	.07652	.07769	.08423	.08457	.09238	44
45	.06486	.06936	.07119	.07665	.07780	.08436	.08469	09252	45
46	06497	.06948	.07130	.07677	.07791	.08449	.08481	.09266	46
47	.06507	.06960	.07141	.07690	.07802	.08463	.08492	.09280	47
48	.06517	.06972	.07151	.07702	.07814	.08476	.08504	.09294	48
49	.06528	.06984	.07162	.07715	.07825	.08489	.08516	.09308	49
50	.06538	.06995	.07173	.07727	.07836	.08503	.08528	.09323	50
51	.06548	.07007	.07184	.07740	.07848	.08516	.08539	.09337	51
52	.06559	.07019	.07195	.07752	.07859	.08529	.08551	.09351	52
53	.06569	.07031	.07206	.07765	.07870	.08542	.08563	.09365	53
54	.06580	.07043	.07216	.07778	.07881	.08556	.08575	.09379	54
	.06590	.07055	.07227	.07790	.07893	.08569	.08586	.09393	55
	06600	.07067	.07238	.07803	.07904	.08582	.08598	.09407	56
	611	.07079	.07249	.07816	.07915	.08596	.08610	.09421	
	621	.07091	.07260	.07828	.07927	.08609	.08622	.09435	
	2	.07103	.07271	.07841	.07938	.08623	.08634	.09449	
	.12	.07115	.07282	.07853	.07950	.08636	.08645	.09464	

′	24°		25°		26°		27		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.08645	.09464	.09369	.10338	.10121	.11260	.10899	.12233	0
1	.08657	.09478	.09382	.10353	.10133	.11276	.10913	.12249	1
2	.08669	.09492	.09394	.10368	.10146	.11292	.10926	.12266	2
3	.08681	.09506	.09406	.10383	.10159	.11308	.10939	.12283	3
4	.08693	.09520	.09418	.10398	.10172	.11323	.10952	.12299	4
5	.08705	.09535	.09431	.10413	.10184	.11339	.10965	.12316	5
6	.08717	.09549	.09443	.10428	.10197	.11355	.10979	.12333	6
7	.08728	.09563	.09455	.10443	.10210	.11371	.10992	.12349	7
8	.08740	.09577	.09468	.10458	.10223	.11387	.11005	.12366	8
9	.08752	.09592	.09480	.10473	.10236	.11403	.11019	.12383	9
10	.08764	.09606	.09493	.10488	.10248	.11419	.11032	.12400	10
11	.08776	.09620	.09505	.10503	.10261	.11435	.11045	.12416	11
12	.08788	.09635	.09517	.10518	.10274	.11451	.11058	.12433	12
13	.08800	.09649	.09530	.10533	.10287	.11467	.11072	.12450	13
14	.08812	.09663	.09542	.10549	.10300	.11483	.11085	.12467	14
15	.08824	.09678	.09554	.10564	.10313	.11499	.11098	.12484	15
16	.08836	.09692	.09567	.10579	.10326	.11515	.11112	.12501	16
17	.08848	.09707	.09579	.10594	.10338	.11531	.11125	.12518	17
18	.08860	.09721	.09592	.10609	.10351	.11547	.11138	.12534	18
19	.08872	.09735	.09604	.10625	.10364	.11563	.11152	.12551	19
20	.08884	.09750	.09617	.10640	.10377	.11579	.11165	.12568	20
21	.08896	.09764	.09629	.10655	.10390	.11595	.11178	.12585	21
22	.08908	.09779	.09642	.10670	.10403	.11611	.11192	.12602	22
23	.08920	.09793	.09654	.10686	.10416	.11627	.11205	.12619	23
24	.08932	.09808	.09666	.10701	.10429	.11643	.11218	.12636	24
25	.08944	.09822	.09679	.10716	.10442	.11659	.11232	.12653	25
26	.08956	.09837	.09691	.10731	.10455	.11675	.11245	.12670	26
27	.08968	.09851	.09704	.10747	.10468	.11691	.11259	.12687	27
28	.08980	.09866	.09716	.10762	.10481	.11708	.11272	.12704	28
29	.08992	.09880	.09729	.10777	.10494	.11724	.11285	.12721	29
30	.09004	.09895	.09741	.10793	.10507	.11740	.11299	.12738	30
31	.09016	.09909	.09754	.10808	.10520	.11756	.11312	.12755	31
32	.09028	.09924	.09767	.10824	.10533	.11772	.11326	.12772	32
33	.09040	.09939	.09779	.10839	.10546	.11789	.11339	.12789	33
34	.09052	.09953	.09792	.10854	.10559	.11805	.11353	.12807	34
35	.09064	.09968	.09804	.10870	.10572	.11821	.11366	.12824	35
36	.09076	.09982	.09817	.10885	.10585	.11838	.11380	.12841	36
37	.09089	.09997	.09829	.10901	.10598	.11854	.11393	.12858	37
38	.09101	.10012	.09842	.10916	.10611	.11870	.11407	.12875	38
39	.09113	.10026	.09854	.10932	.10624	.11886	.11420	.12892	39
40	.09125	.10041	.09867	.10947	.10637	.11903	.11434	.12910	40
41	.09137	.10055	.09880	.10963	.10650	.11919	.11447	.12927	41
42	.09149	.10071	.09892	.10978	.10663	.11936	.11461	.12944	42
43	.09161	.10085	.09905	.10994	.10676	.11952	.11474	.12961	43
44	.09174	.10100	.09918	.11009	.10689	.11968	.11488	.12979	44
45	.09186	.10115	.09930	.11025	.10702	.11985	.11501	.12996	45
46	.09198	.10130	.09943	.11041	.10715	.12001	.11515	.13018	46
47	.09210	.10144	.09955	.11056	.10728	.12018	.11528	.13031	47
48	.09222	.10159	.09968	.11072	.10741	.12034	.11542	.13048	48
49	.09234	.10174	.09981	.11087	.10755	.12051	.11555	.13065	49
50	.09247	.10189	.09993	.11103	.10768	.12067	.11569	.13083	50
51	.00259	.10204	.10006	.11119	.10781	.12084	.11583	.13100	51
52	.09271	.10218	.10019	.11134	.10794	.12100	.11596	.13117	52
53	.09283	.10233	.10032	.11150	.10807	.12117	.11610	.13135	53
54	.09296	.10248	.10044	.11166	.10820	.12133	.11623	.13152	54
55	.09308	.10263	.10057	.11181	.10833	.12150	.11637	.13170	55
56	.09320	.10278	.10070	.11197	.10847	.12166	.11651	.13187	56
57	*.09332*	*.10293*	.10082	.11213	.10860	.12183	.11664	.13205	
58	*.09345*	*.10308*	.10095	.11229	.10873	.12199	.11678	.13222	
59	*.09357*	*.10323*	.10108	.11244	.10886	.12216	.11692	.13240	
60	*.09369*	*.10338*	.10121	.11260	.10899	.12233	.11705	.13257	

′	28°		29°		30°		31°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.11705	.13257	.12538	.14335	.13397	.15470	.14283	.16663	0
1	.11719	.13275	.12552	.14354	.13412	.15489	.14298	.16684	1
2	.11733	.13292	.12566	.14372	.13427	.15509	.14313	.16704	2
3	.11746	.13310	.12580	.14391	.13441	.15528	.14328	.16725	3
4	.11760	.13327	.12595	.14409	.13456	.15548	.14343	.16745	4
5	.11774	.13345	.12609	.14428	.13470	.15567	.14358	.16766	5
6	.11787	.13362	.12623	.14446	.13485	.15587	.14373	.16786	6
7	.11801	.13380	.12637	.14465	.13499	.15606	.14388	.16806	7
8	.11815	.13398	.12651	.14483	.13514	.15626	.14403	.16827	8
9	.11828	.13415	.12665	.14502	.13529	.15645	.14418	.16848	9
10	.11842	.13433	.12679	.14521	.13543	.15665	.14433	.16868	10
11	.11856	.13451	.12694	.14539	.13558	.15684	.14449	.16889	11
12	.11870	.13468	.12708	.14558	.13573	.15704	.14464	.16909	12
13	.11883	.13486	.12722	.14576	.13587	.15724	.14479	.16930	13
14	.11897	.13504	.12736	.14595	.13602	.15743	.14494	.16950	14
15	.11911	.13521	.12750	.14614	.13616	.15763	.14509	.16971	15
16	.11925	.13539	.12765	.14632	.13631	.15782	.14524	.16992	16
17	.11938	.13557	.12779	.14651	.13646	.15802	.14539	.17012	17
18	.11952	.13575	.12793	.14670	.13660	.15822	.14554	.17033	18
19	.11966	.13593	.12807	.14689	.13675	.15841	.14569	.17054	19
20	.11980	.13610	.12822	.14707	.13690	.15861	.14584	.17075	20
21	.11994	.13628	.12836	.14726	.13705	.15881	.14599	.17095	21
22	.12007	.13646	.12850	.14745	.13719	.15901	.14615	.17116	22
23	.12021	.13664	.12864	.14764	.13734	.15920	.14630	.17137	23
24	.12035	.13682	.12879	.14782	.13749	.15940	.14645	.17158	24
25	.12049	.13700	.12893	.14801	.13763	.15960	.14660	.17178	25
26	.12063	.13718	.12907	.14820	.13778	.15980	.14675	.17199	26
27	.12077	.13735	.12921	.14839	.13793	.16000	.14690	.17220	27
28	.12091	.13753	.12936	.14858	.13808	.16019	.14706	.17241	28
29	.12104	.13771	.12950	.14877	.13822	.16039	.14721	.17262	29
30	.12118	.13789	.12964	.14896	.13837	.16059	.14736	.17283	30
31	.12132	.13807	.12979	.14914	.13852	.16079	.14751	.17304	31
32	.12146	.13825	.12993	.14933	.13867	.16099	.14766	.17325	32
33	.12160	.13843	.13007	.14952	.13881	.16119	.14782	.17346	33
34	.12174	.13861	.13022	.14971	.13896	.16139	.14797	.17367	34
35	.12188	.13879	.13036	.14990	.13911	.16159	.14812	.17388	35
36	.12202	.13897	.13051	.15009	.13926	.16179	.14827	.17409	36
37	.12216	.13916	.13065	.15028	.13941	.16199	.14843	.17430	37
38	.12230	.13934	.13079	.15047	.13955	.16219	.14858	.17451	38
39	.12244	.13952	.13094	.15066	.13970	.16239	.14873	.17472	39
40	.12257	.13970	.13108	.15085	.13985	.16259	.14888	.17493	40
41	.12271	.13988	.13122	.15105	.14000	.16279	.14904	.17514	41
42	.12285	.14006	.13137	.15124	.14015	.16299	.14919	.17535	42
43	.12299	.14024	.13151	.15143	.14030	.16319	.14934	.17556	43
44	.12313	.14042	.13166	.15162	.14044	.16339	.14949	.17577	44
45	.12327	.14061	.13180	.15181	.14059	.16359	.14965	.17598	45
46	.12341	.14079	.13195	.15200	.14074	.16380	.14980	.17620	46
47	.12355	.14097	.13209	.15219	.14089	.16400	.14995	.17641	47
48	.12369	.14115	.13223	.15239	.14104	.16420	.15011	.17662	48
49	.12383	.14134	.13238	.15258	.14119	.16440	.15026	.17683	49
50	.12397	.14152	.13252	.15277	.14134	.16460	.15041	.17704	50
51	.12411	.14170	.13267	.15296	.14149	.16481	.15057	.17726	51
52	.12425	.14188	.13281	.15315	.14164	.16501	.15072	.17747	52
53	.12439	.14207	.13296	.15335	.14179	.16521	.15087	.17768	53
54	.12454	.14225	.13310	.15354	.14194	.16541	.15103	.17790	54
55	.12468	.14243	.13325	.15373	.14208	.16562	.15118	.17811	55
[illegible]	[illegible]	.14262	.13339	.15393	.14223	.16582	.15134	.17832	56
[illegible]	[illegible]	.14280	.13354	.15412	.14238	.16602	.15149	.17854	
[illegible]	[illegible]	.14299	.13368	.15431	.14253	.16623	.15164	.17875	
[illegible]	[illegible]	.14317	.13383	.15451	.14268	.16643	.15180	.17896	
[illegible]	[illegible]	.14335	.13397	.15470	.14283	.16663	.15195	.17918	

′	32° Vers.	32° Ex. sec.	33° Vers.	33° Ex. sec.	34° Vers.	34° Ex. sec.	35° Vers.	35° Ex. sec.	′
0	.15195	.17918	.16133	.19236	.17096	.20622	.18085	.22077	0
1	.15211	.17939	.16149	.19259	.17113	.20645	.18101	.22102	1
2	.15226	.17961	.16165	.19281	.17129	.20669	.18118	.22127	2
3	.15241	.17982	.16181	.19304	.17145	.20693	.18135	.22152	3
4	.15257	.18004	.16196	.19327	.17161	.20717	.18152	.22177	4
5	.15272	.18025	.16212	.19349	.17178	.20740	.18168	.22202	5
6	.15288	.18047	.16228	.19372	.17194	.20764	.18185	.22227	6
7	.15303	.18068	.16244	.19394	.17210	.20788	.18202	.22252	7
8	.15319	.18090	.16260	.19417	.17227	.20812	.18218	.22277	8
9	.15334	.18111	.16276	.19440	.17243	.20836	.18235	.22302	9
10	.15350	.18133	.16292	.19463	.17259	.20859	.18252	.22327	10
11	.15365	.18155	.16308	.19485	.17276	.20883	.18269	.22352	11
12	.15381	.18176	.16324	.19508	.17292	.20907	.18286	.22377	12
13	.15396	.18198	.16340	.19531	.17308	.20931	.18302	.22402	13
14	.15412	.18220	.16355	.19554	.17325	.20955	.18319	.22428	14
15	.15427	.18241	.16371	.19576	.17341	.20979	.18336	.22453	15
16	.15443	.18263	.16387	.19599	.17357	.21003	.18353	.22478	16
17	.15458	.18285	.16403	.19622	.17374	.21027	.18369	.22503	17
18	.15474	.18307	.16419	.19645	.17390	.21051	.18386	.22528	18
19	.15489	.18328	.16435	.19668	.17407	.21075	.18403	.22554	19
20	.15505	.18350	.16451	.19691	.17423	.21099	.18420	.22579	20
21	.15520	.18372	.16467	.19713	.17439	.21123	.18437	.22604	21
22	.15536	.18394	.16483	.19736	.17456	.21147	.18454	.22629	22
23	.15552	.18416	.16499	.19759	.17472	.21171	.18470	.22655	23
24	.15567	.18437	.16515	.19782	.17489	.21195	.18487	.22680	24
25	.15583	.18459	.16531	.19805	.17505	.21220	.18504	.22706	25
26	.15598	.18481	.16547	.19828	.17522	.21244	.18521	.22731	26
27	.15614	.18503	.16563	.19851	.17538	.21268	.18538	.22756	27
28	.15630	.18525	.16579	.19874	.17554	.21292	.18555	.22782	28
29	.15645	.18547	.16595	.19897	.17571	.21316	.18572	.22807	29
30	.15661	.18569	.16611	.19920	.17587	.21341	.18588	.22833	30
31	.15676	.18591	.16627	.19944	.17604	.21365	.18605	.22858	31
32	.15692	.18613	.16644	.19967	.17620	.21389	.18622	.22884	32
33	.15708	.18635	.16660	.19990	.17637	.21414	.18639	.22909	33
34	.15723	.18657	.16676	.20013	.17653	.21438	.18656	.22935	34
35	.15739	.18679	.16692	.20036	.17670	.21462	.18673	.22960	35
36	.15755	.18701	.16708	.20059	.17686	.21487	.18690	.22986	36
37	.15770	.18723	.16724	.20083	.17703	.21511	.18707	.23012	37
38	.15786	.18745	.16740	.20106	.17719	.21535	.18724	.23037	38
39	.15802	.18767	.16756	.20129	.17736	.21560	.18741	.23063	39
40	.15818	.18790	.16772	.20152	.17752	.21584	.18758	.23089	40
41	.15833	.18812	.16788	.20176	.17769	.21609	.18775	.23114	41
42	.15849	.18834	.16805	.20199	.17786	.21633	.18792	.23140	42
43	.15865	.18856	.16821	.20222	.17802	.21658	.18809	.23166	43
44	.15880	.18878	.16837	.20246	.17819	.21682	.18826	.23192	44
45	.15896	.18901	.16853	.20269	.17835	.21707	.18843	.23217	45
46	.15912	.18923	.16869	.20292	.17852	.21731	.18860	.23243	46
47	.15928	.18945	.16885	.20316	.17868	.21756	.18877	.23269	47
48	.15943	.18967	.16902	.20339	.17885	.21781	.18894	.23295	48
49	.15959	.18990	.16918	.20363	.17902	.21805	.18911	.23321	49
50	.15975	.19012	.16934	.20386	.17918	.21830	.18928	.23347	50
51	.15991	.19034	.16950	.20410	.17935	.21855	.18945	.23373	51
52	.16006	.19057	.16966	.20433	.17952	.21879	.18962	.23399	52
53	.16022	.19079	.16983	.20457	.17968	.21904	.18979	.23424	53
54	.16038	.19102	.16999	.20480	.17985	.21929	.18996	.23450	54
55	.16054	.19124	.17015	.20504	.18001	.21953	.19013	.23476	55
56	.16070	.19146	.17031	.20527	.18018	.21978	.19030	.23502	56
57	.16085	.19169	.17047	.20551	.18035	.22003	.19047	.23529	5
58	.16101	.19191	.17064	.20575	.18051	.22028	.19064	.23555	
59	.16117	.19214	.17080	.20598	.18068	.22053	.19081	.23581	
60	.16133	.19236	.17096	.20622	.18085	.22077	.19098		

′	36°		37°		38°		39°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.19098	.23607	.20136	.25214	.21199	.26902	.22285	.28676	0
1	.19115	.23633	.20154	.25241	.21217	.26931	.22304	.28706	1
2	.19133	.23659	.20171	.25269	.21235	.26960	.22322	.28737	2
3	.19150	.23685	.20189	.25296	.21253	.26988	.22340	.28767	3
4	.19167	.23711	.20207	.25324	.21271	.27017	.22359	.28797	4
5	.19184	.23738	.20224	.25351	.21289	.27046	.22377	.28828	5
6	.19201	.23764	.20242	.25379	.21307	.27075	.22395	.28858	6
7	.19218	.23790	.20259	.25406	.21324	.27104	.22414	.28889	7
8	.19235	.23816	.20277	.25434	.21342	.27133	.22432	.28919	8
9	.19252	.23843	.20294	.25462	.21360	.27162	.22450	.28950	9
10	.19270	.23869	.20312	.25489	.21378	.27191	.22469	.28980	10
11	.19287	.23895	.20329	.25517	.21396	.27221	.22487	.29011	11
12	.19304	.23922	.20347	.25545	.21414	.27250	.22506	.29042	12
13	.19321	.23948	.20365	.25572	.21432	.27279	.22524	.29072	13
14	.19338	.23975	.20382	.25600	.21450	.27308	.22542	.29103	14
15	.19356	.24001	.20400	.25628	.21468	.27337	.22561	.29133	15
16	.19373	.24028	.20417	.25656	.21486	.27366	.22579	.29164	16
17	.19390	.24054	.20435	.25683	.21504	.27396	.22598	.29195	17
18	.19407	.24081	.20453	.25711	.21522	.27425	.22616	.29226	18
19	.19424	.24107	.20470	.25739	.21540	.27454	.22634	.29256	19
20	.19442	.24134	.20488	.25767	.21558	.27483	.22653	.29287	20
21	.19459	.24160	.20506	.25795	.21576	.27513	.22671	.29318	21
22	.19476	.24187	.20523	.25823	.21595	.27542	.22690	.29349	22
23	.19493	.24213	.20541	.25851	.21613	.27572	.22708	.29380	23
24	.19511	.24240	.20559	.25879	.21631	.27601	.22727	.29411	24
25	.19528	.24267	.20576	.25907	.21649	.27630	.22745	.29442	25
26	.19545	.24293	.20594	.25935	.21667	.27660	.22764	.29473	26
27	.19562	.24320	.20612	.25963	.21685	.27689	.22782	.29504	27
28	.19580	.24347	.20629	.25991	.21703	.27719	.22801	.29535	28
29	.19597	.24373	.20647	.26019	.21721	.27748	.22819	.29566	29
30	.19614	.24400	.20665	.26047	.21739	.27778	.22838	.29597	30
31	.19632	.24427	.20682	.26075	.21757	.27807	.22856	.29628	31
32	.19649	.24454	.20700	.26104	.21775	.27837	.22875	.29659	32
33	.19666	.24481	.20718	.26132	.21794	.27867	.22893	.29690	33
34	.19684	.24508	.20736	.26160	.21812	.27896	.22912	.29721	34
35	.19701	.24534	.20753	.26188	.21830	.27926	.22930	.29752	35
36	.19718	.24561	.20771	.26216	.21848	.27956	.22949	.29784	36
37	.19736	.24588	.20789	.26245	.21866	.27985	.22967	.29815	37
38	.19753	.24615	.20807	.26273	.21884	.28015	.22986	.29846	38
39	.19770	.24642	.20824	.26301	.21902	.28045	.23004	.29877	39
40	.19788	.24669	.20842	.26330	.21921	.28075	.23023	.29909	40
41	.19805	.24696	.20860	.26358	.21939	.28105	.23041	.29940	41
42	.19822	.24723	.20878	.26387	.21957	.28134	.23060	.29971	42
43	.19840	.24750	.20895	.26415	.21975	.28164	.23079	.30003	43
44	.19857	.24777	.20913	.26443	.21993	.28194	.23097	.30034	44
45	.19875	.24804	.20931	.26472	.22012	.28224	.23116	.30066	45
46	.19892	.24832	.20949	.26500	.22030	.28254	.23134	.30097	46
47	.19909	.24859	.20967	.26529	.22048	.28284	.23153	.30129	47
48	.19927	.24886	.20985	.26557	.22066	.28314	.23172	.30160	48
49	.19944	.24913	.21002	.26586	.22084	.28344	.23190	.30192	49
50	.19962	.24940	.21020	.26615	.22103	.28374	.23209	.30223	50
51	.19979	.24967	.21038	.26643	.22121	.28404	.23228	.30255	51
52	.19997	.24995	.21056	.26672	.22139	.28434	.23246	.30287	52
53	.20014	.25022	.21074	.26701	.22157	.28464	.23265	.30318	53
54	.20032	.25049	.21092	.26729	.22176	.28495	.23283	.30350	54
55	.20049	.25077	.21109	.26758	.22194	.28525	.23302	.30382	55
56	.20066	.25104	.21127	.26787	.22212	.28555	.23321	.30413	56
57	.20084	.25131	.21145	.26815	.22231	.28585	.23339	.30445	57
	.20101	.25159	.21163	.26844	.22249	.28615	.23358	.30477	58
	.20119	.25186	.21181	.26873	.22267	.28646	.23377	.30509	
	0136	.25214	.21199	.26902	.22285	.28676	.23396	.30541	

′	40°		41°		42°		43°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.23396	.30541	.24529	.32501	.25686	.34563	.26865	.36733	0
1	.23414	.30573	.24548	.32535	.25705	.34599	.26884	.36770	1
2	.23433	.30605	.24567	.32568	.25724	.34634	.26904	.36807	2
3	.23452	.30636	.24586	.32602	.25744	.34669	.26924	.36844	3
4	.23470	.30668	.24605	.32636	.25763	.34704	.26944	.36881	4
5	.23489	.30700	.24625	.32669	.25783	.34740	.26964	.36919	5
6	.23508	.30732	.24644	.32703	.25802	.34775	.26984	.36956	6
7	.23527	.30764	.24663	.32737	.25822	.34811	.27004	.36993	7
8	.23545	.30796	.24682	.32770	.25841	.34846	.27024	.37030	8
9	.23564	.30829	.24701	.32804	.25861	.34882	.27043	.37068	9
10	.23583	.30861	.24720	.32838	.25880	.34917	.27063	.37105	10
11	.23602	.30893	.24739	.32872	.25900	.34953	.27083	.37143	11
12	.23620	.30925	.24759	.32905	.25920	.34988	.27103	.37180	12
13	.23639	.30957	.24778	.32939	.25939	.35024	.27123	.37218	13
14	.23658	.30089	.24797	.32973	.25959	.35060	.27143	.37255	14
15	.23677	.31022	.24816	.33007	.25978	.35095	.27163	.37293	15
16	.23696	.31054	.24835	.33041	.25998	.35131	.27183	.37330	16
17	.23714	.31086	.24854	.33075	.26017	.35167	.27203	.37368	17
18	.23733	.31119	.24874	.33109	.26037	.35203	.27223	.37406	18
19	.23752	.31151	.24893	.33143	.26056	.35238	.27243	.37443	19
20	.23771	.31183	.24912	.33177	.26076	.35274	.27263	.37481	20
21	.23790	.31216	.24931	.33211	.26096	.35310	.27283	.37519	21
22	.23808	.31248	.24950	.33245	.26115	.35346	.27303	.37556	22
23	.23827	.31281	.24970	.33279	.26135	.35382	.27323	.37594	23
24	.23846	.31313	.24989	.33314	.26154	.35418	.27343	.37632	24
25	.23865	.31346	.25008	.33348	.26174	.35454	.27363	.37670	25
26	.23884	.31378	.25027	.33382	.26194	.35490	.27383	.37708	26
27	.23903	.31411	.25047	.33416	.26213	.35526	.27403	.37746	27
28	.23922	.31443	.25066	.33451	.26233	.35562	.27423	.37784	28
29	.23941	.31476	.25085	.33485	.26253	.35598	.27443	.37822	29
30	.23959	.31509	.25104	.33519	.26272	.35634	.27463	.37860	30
31	.23978	.31541	.25124	.33554	.26292	.35670	.27483	.37898	31
32	.23997	.31574	.25143	.33588	.26312	.35707	.27503	.37936	32
33	.24016	.31607	.25162	.33622	.26331	.35743	.27523	.37974	33
34	.24035	.31640	.25182	.33657	.26351	.35779	.27543	.38012	34
35	.24054	.31672	.25201	.33691	.26371	.35815	.27563	.38051	35
36	.24073	.31705	.25220	.33726	.26390	.35852	.27583	.38089	36
37	.24092	.31738	.25240	.33760	.26410	.35888	.27003	.38127	37
38	.24111	.31771	.25259	.33795	.26430	.35924	.27623	.38165	38
39	.24130	.31804	.25278	.33830	.26449	.35961	.27643	.38204	39
40	.24149	.31837	.25297	.33864	.26469	.35997	.27063	.38242	40
41	.24168	.31870	.25317	.33899	.26489	.36034	.27683	.38280	41
42	.24187	.31903	.25336	.33934	.26509	.36070	.27703	.38319	42
43	.24206	.31936	.25356	.33968	.26528	.36107	.27723	.38357	43
44	.24225	.31969	.25375	.34003	.26548	.36143	.27743	.38396	44
45	.24244	.32002	.25394	.34038	.26568	.36180	.27764	.38434	45
46	.24262	.32035	.25414	.34073	.26588	.36217	.27784	.38473	46
47	.24281	.32068	.25433	.34108	.26607	.36253	.27804	.38512	47
48	.24300	.32101	.25452	.34142	.26627	.36290	.27824	.38550	48
49	.24320	.32134	.25472	.34177	.26647	.36327	.27844	.38589	49
50	.24339	.32168	.25491	.34212	.26667	.36363	.27864	.38628	50
51	.24358	.32201	.25511	.34247	.26686	.36400	.27884	.38666	51
52	.24377	.32234	.25530	.34282	.26706	.36437	.27905	.38705	52
53	.24396	.32267	.25549	.34317	.26726	.36474	.27925	.38744	53
54	.24415	.32301	.25569	.34352	.26746	.36511	.27945	.38783	54
55	.24434	.32334	.25588	.34387	.26766	.36548	.27965	.38822	55
56	.24453	.32368	.25608	.34423	.26785	.36585	.27985	.38860	56
57	.24472	.32401	.25627	.34458	.26805	.36622	.28005	.38899	57
58	.24491	.32434	.25647	.34493	.26825	.36659	.28025	.38938	58
59	.24510	.32468	.25666	.34528	.26845	.36696	.28046	.38977	
60	.24529	.32501	.25686	.34563	.26865	.36733	.28066	.39016	

′	44°		45°		46°		47°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.28066	.39016	.29289	.41421	.30534	.43956	.31800	.46628	0
1	.28086	.39055	.29310	.41463	.30555	.43999	.31821	.46674	1
2	.28106	.39095	.29330	.41504	.30576	.44042	.31843	.46719	2
3	.28127	.39134	.29351	.41545	.30597	.44086	.31864	.46765	3
4	.28147	.39173	.29372	.41586	.30618	.44129	.31885	.46811	4
5	.28167	.39212	.29392	.41627	.30639	.44173	.31907	.46857	5
6	.28187	.39251	.29413	.41669	.30660	.44217	.31928	.46903	6
7	.28208	.39291	.29433	.41710	.30681	.44260	.31949	.46949	7
8	.28228	.39330	.29454	.41752	.30702	.44304	.31971	.46995	8
9	.28248	.39369	.29475	.41793	.30723	.44347	.31992	.47041	9
10	.28268	.39409	.29495	.41835	.30744	.44391	.32013	.47087	10
11	.28289	.39448	.29516	.41876	.30765	.44435	.32035	.47134	11
12	.28309	.39487	.29537	.41918	.30786	.44479	.32056	.47180	12
13	.28329	.39527	.29557	.41959	.30807	.44523	.32077	.47226	13
14	.28350	.39566	.29578	.42001	.30828	.44567	.32099	.47272	14
15	.28370	.39606	.29599	.42042	.30849	.44610	.32120	.47319	15
16	.28390	.39646	.29619	.42084	.30870	.44654	.32141	.47365	16
17	.28410	.39685	.29640	.42126	.30891	.44698	.32163	.47411	17
18	.28431	.39725	.29661	.42168	.30912	.44742	.32184	.47458	18
19	.28451	.39764	.29681	.42210	.30933	.44787	.32205	.47504	19
20	.28471	.39804	.29702	.42251	.30954	.44831	.32227	.47551	20
21	.28492	.39844	.29723	.42293	.30975	.44875	.32248	.47598	21
22	.28512	.39884	.29743	.42335	.30996	.44919	.32270	.47644	22
23	.28532	.39924	.29764	.42377	.31017	.44963	.32291	.47691	23
24	.28553	.39963	.29785	.42419	.31038	.45007	.32312	.47738	24
25	.28573	.40003	.29805	.42461	.31059	.45052	.32334	.47784	25
26	.28593	.40043	.29826	.42503	.31080	.45096	.32355	.47831	26
27	.28614	.40083	.29847	.42545	.31101	.45141	.32377	.47878	27
28	.28634	.40123	.29868	.42587	.31122	.45185	.32398	.47925	28
29	.28655	.40163	.29888	.42630	.31143	.45229	.32420	.47972	29
30	.28675	.40203	.29909	.42672	.31165	.45274	.32441	.48019	30
31	.28695	.40243	.29930	.42714	.31186	.45319	.32462	.48066	31
32	.28716	.40283	.29951	.42756	.31207	.45363	.32484	.48113	32
33	.28736	.40324	.29971	.42799	.31228	.45408	.32505	.48160	33
34	.28757	.40364	.29992	.42841	.31249	.45452	.32527	.48207	34
35	.28777	.40404	.30013	.42883	.31270	.45497	.32548	.48254	35
36	.28797	.40444	.30034	.42926	.31291	.45542	.32570	.48301	36
37	.28818	.40485	.30054	.42968	.31312	.45587	.32591	.48349	37
38	.28838	.40525	.30075	.43011	.31334	.45631	.32613	.48396	38
39	.28859	.40565	.30096	.43053	.31355	.45676	.32634	.48443	39
40	.28879	.40606	.30117	.43096	.31376	.45721	.32656	.48491	40
41	.28900	.40646	.30138	.43139	.31397	.45766	.32677	.48538	41
42	.28920	.40687	.30158	.43181	.31418	.45811	.32699	.48586	42
43	.28941	.40727	.30179	.43224	.31439	.45856	.32720	.48633	43
44	.28961	.40768	.30200	.43267	.31461	.45901	.32742	.48681	44
45	.28981	.40808	.30221	.43310	.31482	.45946	.32763	.48728	45
46	.29002	.40849	.30242	.43352	.31503	.45992	.32785	.48776	46
47	.29022	.40890	.30263	.43395	.31524	.46037	.32806	.48824	47
48	.29043	.40930	.30283	.43438	.31545	.46082	.32828	.48871	48
49	.29063	.40971	.30304	.43481	.31567	.46127	.32849	.48919	49
50	.29084	.41012	.30325	.43524	.31588	.46173	.32871	.48967	50
51	.29104	.41053	.30346	.43567	.31609	.46218	.32893	.49015	51
52	.29125	.41093	.30367	.43610	.31630	.46263	.32914	.49063	52
53	.29145	.41134	.30388	.43653	.31651	.46309	.32936	.49111	53
54	.29166	.41175	.30409	.43696	.31673	.46354	.32957	.49159	54
55	.29187	.41216	.30430	.43739	.31694	.46400	.32979	.49207	55
56	.29207	.41257	.30451	.43783	.31715	.46445	.33001	.49255	56
	.29228	.41298	.30471	.43826	.31736	.46491	.33022	.49303	57
	.29248	.41339	.30492	.43869	.31758	.46537	.33044	.49351	58
	9269	.41380	.30513	.43912	.31779	.46582	.33065	.49399	59
	9	.41421	.30534	.43956	.31800	.46628	.33087	.49448	

′	48°		49°		50°		51°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.33087	.49448	.34394	.52425	.35721	.55572	.37068	.58902	0
1	.33109	.49496	.34416	.52476	.35744	.55626	.37091	.58959	1
2	.33130	.49544	.34438	.52527	.35766	.55680	.37113	.59016	2
3	.33152	.49593	.34400	.52579	.35788	.55734	.37136	.59073	3
4	.33173	.49641	.34482	.52630	.35810	.55789	.37158	.59130	4
5	.33195	.49690	.34504	.52681	.35833	.55843	.37181	.59188	5
6	.33217	.49738	.34526	.52732	.35855	.55897	.37204	.59245	6
7	.33238	.49787	.34548	.52784	.35877	.55951	.37226	.59302	7
8	.33260	.49835	.34570	.52835	.35900	.56005	.37249	.59360	8
9	.33282	.49884	.34592	.52886	.35922	.56060	.37272	.59418	9
10	.33303	.49933	.34614	.52938	.35944	.56114	.37294	.59475	10
11	.33325	.49981	.34636	.52989	.35967	.56169	.37317	.59533	11
12	.33347	.50030	.34658	.53041	.35989	.56223	.37340	.59590	12
13	.33368	.50079	.34680	.53092	.36011	.56278	.37362	.59648	13
14	.33390	.50128	.34702	.53144	.36034	.56332	37385	59706	14
15	.33412	.50177	.34724	.53196	.36056	.56387	37408	.59764	15
16	.33434	.50226	.34746	.53247	.36078	.56442	.37430	59822	16
17	.33455	.50275	.34768	.53299	.36101	.56497	.37453	.59880	17
18	.33477	.50324	.34790	.53351	.36123	.56551	37476	.59938	18
19	.33499	.50373	.34812	.53403	.36146	.56606	.37498	.59996	19
20	.33520	.50422	.34834	.53455	.36168	.56661	.37521	.60054	20
21	.33542	.50471	.34856	.53507	.36190	.56716	.37544	.60112	21
22	.33564	.50521	.34878	.53559	.36213	.56771	.37567	60171	22
23	.33586	.50570	.34900	.53611	.36235	.56826	.37589	.60229	23
24	.33607	.50619	.34923	.53663	.36258	.56881	.37612	.60287	24
25	.33629	.50669	.34945	.53715	.36280	.56937	37635	.60346	25
26	.33651	.50718	.34967	.53768	.36302	.56992	.37658	.60404	26
27	.33673	.50767	.34989	.53820	.36325	.57047	.37680	.60463	27
28	.33694	.50817	.35011	.53872	.36347	.57103	.37703	.60521	28
29	.33716	.50866	.35033	.53924	.36370	.57158	.37726	.60580	29
30	.33738	.50916	.35055	.53977	.36392	.57213	.37749	.60639	30
31	.33760	.50966	.35077	.54029	.36415	.57269	.37771	.60698	31
32	.33782	.51015	.35099	.54082	.36437	.57324	.37794	.60756	32
33	.33803	.51065	.35122	.54134	.36460	.57380	.37817	.60815	33
34	.33825	.51115	.35144	.54187	.36482	.57436	.37840	.60874	34
35	.33847	.51165	.35166	.54240	.36504	.57491	.37862	.60933	35
36	.33869	.51215	.35188	.54292	.36527	.57547	.37885	.60992	36
37	.33891	.51265	.35210	.54345	.36549	.57603	.37908	.61051	37
38	.33912	.51314	.35232	.54398	.36572	.57659	.37931	.61111	38
39	.33934	.51364	.35254	.54451	.36594	.57715	.37954	.61170	39
40	.33956	.51415	.35277	.54504	.36617	.57771	.37976	.61229	40
41	.33978	.51465	.35299	.54557	.36639	.57827	.37999	.61288	41
42	.34000	.51515	.35321	.54610	.36662	.57883	.38022	.61348	42
43	.34022	.51565	.35343	.54663	.36684	.57939	.38045	.61407	43
44	.34044	.51615	.35365	.54716	.36707	.57995	.38068	.61467	44
45	.34065	.51665	.35388	.54769	.36729	.58051	.38091	.61526	45
46	.34087	.51716	.35410	.54822	.36752	.58108	.38113	.61586	46
47	.34109	.51766	.35432	.54876	.36775	.58164	.38136	.61646	47
48	.34131	.51817	.35454	.54929	.36797	.58221	.38159	.61705	48
49	.34153	.51867	.35476	.54982	.36820	.58277	.38182	.61765	49
50	.34175	.51918	.35499	.55036	.36842	.58333	.38205	.61825	50
51	.34197	.51968	.35521	.55089	.36865	.58390	.38228	.61885	51
52	.34219	.52019	.35543	.55143	.36887	.58447	.38251	.61945	52
53	.34241	.52069	.35565	.55196	.36910	.58503	.38274	.62005	53
54	.34262	.52120	.35588	.55250	.36932	.58560	.38296	.62065	54
55	.34284	.52171	.35610	.55303	.36955	.58617	.38319	.62125	55
56	.34306	.52222	.35632	.55357	.36978	.58674	.38342	.62185	56
57	.34328	.52273	.35654	.55411	.37000	.58731	.38365	.62246	57
58	.34350	.52323	.35677	.55465	.37023	.58788	.38388	.62306	5
59	.34372	.52374	.35699	.55518	.37045	.58845	.38411	.62366	
0	.34394	.52425	.35721	.55572	.37068	.58902	.38434	.62427	

′	52°		53°		54°		55°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.38434	.62427	.39819	.66164	.41221	.70130	.42642	.74345	0
1	.38457	.62487	.39842	.66228	.41245	.70198	.42666	.74417	1
2	.38480	.62548	.39865	.66292	.41269	.70267	.42690	.74490	2
3	.38503	.62609	.39888	.66357	.41292	.70335	.42714	.74562	3
4	.38526	.62669	.39911	.66421	.41316	.70403	.42738	.74635	4
5	.38549	.62730	.39935	.66486	.41339	.70472	.42762	.74708	5
6	.38571	.62791	.39958	.66550	.41363	.70540	.42785	.74781	6
7	.38594	.62852	.39981	.66615	.41386	.70609	.42809	.74854	7
8	.38617	.62913	.40005	.66679	.41410	.70677	.42833	.74927	8
9	.38640	.62974	.40028	.66744	.41433	.70746	.42857	.75000	9
10	.38663	.63035	.40051	.66809	.41457	.70815	.42881	.75073	10
11	.38686	.63096	.40074	.66873	.41481	.70884	.42905	.75146	11
12	.38709	.63157	.40098	.66938	.41504	.70953	.42929	.75219	12
13	.38732	.63218	.40121	.67003	.41528	.71022	.42953	.75293	13
14	.38755	.63279	.40144	.67068	.41551	.71091	.42976	.75366	14
15	.38778	.63341	.40168	.67133	.41575	.71160	.43000	.75440	15
16	.38801	.63402	.40191	.67199	.41599	.71229	.43024	.75513	16
17	.38824	.63464	.40214	.67264	.41622	.71298	.43048	.75587	17
18	.38847	.63525	.40237	.67329	.41646	.71368	.43072	.75661	18
19	38870	63587	.40261	.67394	.41670	.71437	.43096	.75734	19
20	.38893	.63648	.40284	.67460	.41693	.71506	.43120	.75808	20
21	.38916	.63710	.40307	.67525	.41717	.71576	.43144	.75882	21
22	.38939	.63772	.40331	.67591	.41740	.71646	43168	.75956	22
23	.38962	.63834	.40354	.67656	.41764	.71715	.43192	.76031	23
24	38985	.63895	.40378	.67722	.41788	.71785	.43216	.76105	24
25	.39009	.63957	.40401	.67788	.41811	.71855	.43240	.76179	25
26	.39032	.64019	.40424	.67853	.41835	.71925	.43264	.76253	26
27	.39055	64081	.40448	.67919	.41859	.71995	.43287	.76328	27
28	.39078	.64144	.40471	.67985	.41882	.72065	.43311	.76402	28
29	.39101	.64206	.40494	.68051	.41906	.72135	.43335	.76477	29
30	.39124	.64268	.40518	.68117	.41930	.72205	.43359	.76552	30
31	.39147	.64330	.40541	.68183	.41953	.72275	.43383	.76626	31
32	.39170	.64393	.40565	.68250	.41977	.72346	.43407	.76701	32
33	.39193	.64455	.40588	.68316	.42001	.72416	.43431	.76776	33
34	.39216	.64518	.40611	.68382	.42024	.72487	.43455	.76851	34
35	.39239	.64580	.40635	.68449	.42048	.72557	.43479	.76926	35
36	.39262	.64643	.40658	.68515	.42072	.72628	.43503	.77001	36
37	.39286	.64705	.40682	.68582	.42096	.72698	.43527	.77077	37
38	39309	.64768	.40705	.68648	.42119	.72769	.43551	.77152	38
39	.39332	.64831	.40728	.68715	.42143	.72840	.43575	.77227	39
40	.39355	.64894	.40752	.68782	.42167	.72911	.43599	.77303	40
41	.39378	.64957	.40775	.68848	.42191	.72982	.43623	.77378	41
42	.39401	.65020	.40799	68915	.42214	.73053	.43647	.77454	42
43	.39424	.65083	.40822	.68982	.42238	73124	.43671	.77530	43
44	.39447	.65146	.40846	69049	.42262	.73195	.43695	.77606	44
45	.39471	.65209	.40869	.69116	.42285	.73267	.43720	.77681	45
46	.39494	.65272	.40893	.69183	.42309	.73338	.43744	.77757	46
47	39517	.65336	.40916	.69250	.42333	.73409	.43768	.77833	47
48	.39540	.65399	.40939	.69318	.42357	.73481	.43792	.77910	48
49	.39563	.65462	.40963	.69385	.42381	.73552	.43816	.77986	49
50	.39586	.65526	.40986	.69452	.42404	.73624	.43840	.78062	50
51	.39610	.65589	.41010	.69520	.42428	.73696	.43864	.78138	51
52	.39633	.65653	.41033	.69587	.42452	.73768	.43888	.78215	52
53	.39656	.65717	.41057	.69655	.42476	.73840	.43912	.78291	53
54	.39679	.65780	.41080	.69723	.42499	.73911	.43936	.78368	54
55	.39702	.65844	.41104	.69790	.42523	.73983	.43960	.78445	55
56	.39726	.65908	.41127	.69858	.42547	74056	.43984	.78521	56
	.39749	.65972	.41151	.69926	.42571	.74128	.44008	.78598	57
	.39772	.66036	.41174	.69994	.42595	.74200	.44032	.78675	58
	[illegible]95	.66100	.41198	.70062	.42619	.74272	.44057	.78752	
	[illegible]19	.66164	.41221	.70130	.42642	.74345	44081	.78829	

′	56°		57°		58°		59°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.44081	.78829	.45536	.83608	.47008	.88708	.48496	.94160	0
1	.44105	.78906	.45560	.83690	.47033	.88796	.48521	.94254	1
2	.44129	.78984	.45585	.83773	.47057	.88884	.48546	.94349	2
3	.44153	.79061	.45609	.83855	.47082	.88972	.48571	.94443	3
4	.44177	.79138	.45634	.83938	.47107	.89060	.48596	.94537	4
5	.44201	.79216	.45658	.84020	.47131	.89148	.48621	.94632	5
6	.44225	.79293	.45683	.84103	.47156	.89237	.48646	.94726	6
7	.44250	.79371	.45707	.84186	.47181	.89325	.48671	.94821	7
8	.44274	.79449	.45731	.84269	.47206	.89414	.48696	.94916	8
9	.44298	.79527	.45756	.84352	.47230	.89503	.48721	.95011	9
10	.44322	.79604	.45780	.84435	.47255	.89591	.48746	.95106	10
11	.44346	.79682	.45805	.84518	.47280	.89680	.48771	.95201	11
12	.44370	.79761	.45829	.84601	.47304	.89769	.48796	.95296	12
13	.44395	.79839	.45854	.84685	.47329	.89858	.48821	.95392	13
14	.44419	.79917	.45878	.84768	.47354	.89948	.48846	.95487	14
15	.44443	.79995	.45903	.84852	.47379	.90037	.48871	.95583	15
16	.44467	.80074	.45927	.84935	.47403	.90126	.48896	.95678	16
17	.44491	.80152	.45951	.85019	.47428	.90216	.48921	.95774	17
18	.44516	.80231	.45976	.85103	.47453	.90305	.48946	.95870	18
19	.44540	.80309	.46000	.85187	.47478	.90395	.48971	.95966	19
20	.44564	.80388	.46025	.85271	.47502	.90485	.48996	.96062	20
21	.44588	.80467	.46049	.85355	.47527	.90575	.49021	.96158	21
22	.44612	.80546	.46074	.85439	.47552	.90665	.49046	.96255	22
23	.44637	.80625	.46098	.85523	.47577	.90755	.49071	.96351	23
24	.44661	.80704	.46123	.85608	.47601	.90845	.49096	.96448	24
25	.44685	.80783	.46147	.85692	.47626	.90935	.49121	.96544	25
26	.44709	.80862	.46172	.85777	.47651	.91026	.49146	.96641	26
27	.44734	.80942	.46196	.85861	.47676	.91116	.49171	.96738	27
28	.44758	.81021	.46221	.85946	.47701	.91207	.49196	.96835	28
29	.44782	.81101	.46246	.86031	.47725	.91297	.49221	.96932	29
30	.44806	.81180	.46270	.86116	.47750	.91388	.49246	.97029	30
31	.44831	.81260	.46295	.86201	.47775	.91479	.49271	.97127	31
32	.44855	.81340	.46319	.86286	.47800	.91570	.49296	.97224	32
33	.44879	.81419	.46344	.86371	.47825	.91661	.49321	.97322	33
34	.44903	.81499	.46368	.86457	.47849	.91752	.49346	.97420	34
35	.44928	.81579	.46393	.86542	.47874	.91844	.49372	.97517	35
36	.44952	.81659	.46417	.86627	.47899	.91935	.49397	.97615	36
37	.44976	.81740	.46442	.86713	.47924	.92027	.49422	.97713	37
38	.45001	.81820	.46466	.86799	.47949	.92118	.49447	.97811	38
39	.45025	.81900	.46491	.86885	.47974	.92210	.49472	.97910	39
40	.45049	.81981	.46516	.86970	.47998	.92302	.49497	.98008	40
41	.45073	.82061	.46540	.87056	.48023	.92394	.49522	.98107	41
42	.45098	.82142	.46565	.87142	.48048	.92486	.49547	.98205	42
43	.45122	.82222	.46589	.87229	.48073	.92578	.49572	.98304	43
44	.45146	.82303	.46614	.87315	.48098	.92670	.49597	.98403	44
45	.45171	.82384	.46639	.87401	.48123	.92762	.49623	.98502	45
46	.45195	.82465	.46663	.87488	.48148	.92855	.49648	.98601	46
47	.45219	.82546	.46688	.87574	.48172	.92947	.49673	.98700	47
48	.45244	.82627	.46712	.87661	.48197	.93040	.49698	.98799	48
49	.45268	.82709	.46737	.87748	.48222	.93133	.49723	.98899	49
50	.45292	.82790	.46762	.87834	.48247	.93226	.49748	.98998	50
51	.45317	.82871	.46786	.87921	.48272	.93319	.49773	.99098	51
52	.45341	.82953	.46811	.88008	.48297	.93412	.49799	.99198	52
53	.45365	.83034	.46836	.88095	.48322	.93505	.49824	.99298	53
54	.45390	.83116	.46860	.88183	.48347	.93598	.49849	.99308	54
55	.45414	.83198	.46885	.88270	.48372	.93692	.49874	99498	55
56	.45439	.83280	.46909	.88357	.48396	.93785	.49899	.99598	56
57	.45463	.83362	.46934	.88445	.48421	.93879	.49924	.99698	57
58	.45487	.83444	.46959	.88532	.48446	.93973	.49950	.99799	58
59	.45512	.83526	.46983	.88620	.48471	.94066	.49975	.99899	59
60	.45536	.83608	.47008	.88708	.48496	.94160	.50000	1.00000	60

′	60°		61°		62°		63°	
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.
0	.50000	1.00000	.51519	1.06267	.53053	1.13005	.54601	1.20269
1	.50025	1.00101	.51544	1.06375	.53079	1.13122	.54627	1.20395
2	.50050	1.00202	.51570	1.06483	.53104	1.13239	.54653	1.20521
3	.50076	1.00303	.51595	1.06592	.53130	1.13356	.54679	1.20647
4	.50101	1.00404	.51621	1.06701	.53156	1.13473	.54705	1.20773
5	.50126	1.00505	.51646	1.06809	.53181	1.13590	.54731	1.20900
6	.50151	1.00607	.51672	1.06918	.53207	1.13707	.54757	1.21026
7	.50176	1.00708	.51697	1.07027	.53233	1.13825	.54782	1.21153
8	.50202	1.00810	.51723	1.07137	.53258	1.13942	.54808	1.21280
9	.50227	1.00912	.51748	1.07246	.53284	1.14060	.54834	1.21407
10	.50252	1.01014	.51774	1.07356	.53310	1.14178	.54860	1.21535
11	.50277	1.01116	.51799	1.07465	.53336	1.14296	.54886	1.21662
12	.50303	1.01218	.51825	1.07575	.53361	1.14414	.54912	1.21790
13	.50328	1.01320	.51850	1.07685	.53387	1.14533	.54938	1.21918
14	.50353	1.01422	.51876	1.07795	.53413	1.14651	.54964	1.22045
15	.50378	1.01525	.51901	1.07905	.53439	1.14770	.54990	1.22174
16	.50404	1.01628	.51927	1.08015	.53464	1.14889	.55016	1.22302
17	.50429	1.01730	.51952	1.08126	.53490	1.15008	.55042	1.22430
18	.50454	1.01833	.51978	1.08236	.53516	1.15127	.55068	1.22559
19	.50479	1.01936	.52003	1.08347	.53542	1.15246	.55094	1.22688
20	.50505	1.02039	.52029	1.08458	.53567	1.15366	.55120	1.22817
21	.50530	1.02143	.52054	1.08569	.53593	1.15485	.55146	1.22946
22	.50555	1.02246	.52080	1.08680	.53619	1.15605	.55172	1.23075
23	.50581	1.02349	.52105	1.08791	.53645	1.15725	.55198	1.23205
24	.50606	1.02453	.52131	1.08903	.53670	1.15845	.55224	1.23334
25	.50631	1.02557	.52156	1.09014	.53696	1.15965	.55250	1.23464
26	.50656	1.02661	.52182	1.09126	.53722	1.16085	.55276	1.23594
27	.50682	1.02765	.52207	1.09238	.53748	1.16206	.55302	1.23724
28	.50707	1.02869	.52233	1.09350	.53774	1.16326	.55328	1.23855
29	.50732	1.02973	.52259	1.09462	.53799	1.16447	.55354	1.23985
30	.50758	1.03077	.52284	1.09574	.53825	1.16568	.55380	1.24116
31	.50783	1.03182	.52310	1.09686	.53851	1.16689	.55406	1.24247
32	.50808	1.03286	.52335	1.09799	.53877	1.16810	.55432	1.24378
33	.50834	1.03391	.52361	1.09911	.53903	1.16932	.55458	1.24509
34	.50859	1.03496	.52386	1.10024	.53928	1.17053	.55484	1.24640
35	.50884	1.03601	.52412	1.10137	.53954	1.17175	.55510	1.24772
36	.50910	1.03706	.52438	1.10250	.53980	1.17297	.55536	1.24903
37	.50935	1.03811	.52463	1.10363	.54006	1.17419	.55563	1.25035
38	.50960	1.03916	.52489	1.10477	.54032	1.17541	.55589	1.25167
39	.50986	1.04022	.52514	1.10590	.54058	1.17663	.55615	1.25300
40	.51011	1.04128	.52540	1.10704	.54083	1.17786	.55641	1.25432
41	.51036	1.04233	.52566	1.10817	.54109	1.17909	.55667	1.25565
42	.51062	1.04339	.52591	1.10931	.54135	1.18031	.55693	1.25697
43	.51087	1.04445	.52617	1.11045	.54161	1.18154	.55719	1.25830
44	.51113	1.04551	.52642	1.11159	.54187	1.18277	.55745	1.25963
45	.51138	1.04658	.52668	1.11274	.54213	1.18401	.55771	1.26097
46	.51163	1.04764	.52694	1.11388	.54238	1.18524	.55797	1.26230
47	.51189	1.04870	.52719	1.11503	.54264	1.18648	.55823	1.26364
48	.51214	1.04977	.52745	1.11617	.54290	1.18772	.55849	1.26498
49	.51239	1.05084	.52771	1.11732	.54316	1.18895	.55876	1.26632
50	.51265	1.05191	.52796	1.11847	.54342	1.19019	.55902	1.26766
51	.51290	1.05298	.52822	1.11963	.54368	1.19144	.55928	1.26900
52	.51316	1.05405	.52848	1.12078	.54394	1.19268	.55954	1.27035
53	.51341	1.05512	.52873	1.12193	.54420	1.19393	.55980	1.27169
54	.51366	1.05619	.52899	1.12309	.54446	1.19517	.56006	1.27304
55	.51392	1.05727	.52924	1.12425	.54471	1.19642	.56032	1.27439
56	.51417	1.05835	.52950	1.12540	.54497	1.19767	.56058	1.27574
[illegible]	.51443	1.05942	.52976	1.12657	.54523	1.19892	.56084	1.27710
[illegible]	[illegible]	1.06050	.53001	1.12773	.54549	1.20018	.56111	1.27845
[illegible]	[illegible]	1.06158	.53027	1.12889	.54575	1.20143	.56137	1.27981
[illegible]	[illegible]	1.06267	.53053	1.13005	.54601	1.20269	.56163	1.2811

64°		65°		66°		67°		
ers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
6163	1.28117	.57738	1.36620	.59326	1.45859	.60927	1.55930	0
6189	1.28253	.57765	1.36768	.59353	1.46020	.60954	1.56106	1
6215	1.28390	.57791	1.36916	.59379	1.46181	.60980	1.56282	2
6241	1.28526	.57817	1.37064	.59406	1.46342	.61007	1.56458	3
6267	1.28663	.57844	1.37212	.59433	1.46504	.61034	1.56634	4
6294	1.28800	.57870	1.37361	.59459	1.46665	.61061	1.56811	5
6320	1.28937	.57896	1.37509	.59486	1.46827	.61088	1.56988	6
6346	1.29074	.57923	1.37658	.59512	1.46989	.61114	1.57165	7
6372	1.29211	.57949	1.37808	.59539	1.47152	.61141	1.57342	8
56398	1.29349	.57976	1.37957	.59566	1.47314	.61168	1.57520	9
56425	1.29487	.58002	1.38107	.59592	1.47477	.61195	1.57698	10
56451	1.29625	.58028	1.38256	.59619	1.47640	.61222	1.57876	11
56477	1.29763	.58055	1.38406	.59645	1.47804	.61248	1.58054	12
56503	1.29901	.58081	1.38556	.59672	1.47967	.61275	1.58233	13
56529	1.30040	.58108	1.38707	.59699	1.48131	.61302	1.58412	14
56555	1.30179	.58134	1.38857	.59725	1.48295	.61329	1.58591	15
56582	1.30318	.58160	1.39008	.59752	1.48459	.61356	1.58771	16
56608	1.30457	.58187	1.39159	.59779	1.48624	.61383	1.58950	17
56634	1.30596	.58213	1.39311	.59805	1.48789	.61409	1.59130	18
56660	1.30735	.58240	1.39462	.59832	1.48954	.61436	1.59311	19
.56687	1.30875	.58266	1.39614	.59859	1.49119	.61463	1.59491	20
.56713	1.31015	.58293	1.39766	.59885	1.49284	.61490	1.59672	21
.56739	1.31155	.58319	1.39918	.59912	1.49450	.61517	1.59853	22
.56765	1.31295	.58345	1.40070	.59938	1.49616	.61544	1.60035	23
.56791	1.31436	.58372	1.40222	.59965	1.49782	.61570	1.60217	24
.56818	1.31576	.58398	1.40375	.59992	1.49948	.61597	1.60399	25
.56844	1.31717	.58425	1.40528	.60018	1.50115	.61624	1.60581	26
.56870	1.31858	.58451	1.40681	.60045	1.50282	.61651	1.60763	27
.56896	1.31999	.58478	1.40835	.60072	1.50449	.61678	1.60946	28
.56923	1.32140	.58504	1.40988	.60098	1.50617	.61705	1.61129	29
.56949	1.32282	.58531	1.41142	.60125	1.50784	.61732	1.61313	30
.56975	1.32424	.58557	1.41296	.60152	1.50952	.61759	1.61496	31
.57001	1.32566	.58584	1.41450	.60178	1.51120	.61785	1.61680	32
.57028	1.32708	.58610	1.41605	.60205	1.51289	.61812	1.61864	33
.57054	1.32850	.58637	1.41760	.60232	1.51457	.61839	1.62049	34
.57080	1.32993	.58663	1.41914	.60259	1.51626	.61866	1.62234	35
.57106	1.33135	.58690	1.42070	.60285	1.51795	.61893	1.62419	36
.57133	1.33278	.58716	1.42225	.60312	1.51965	.61920	1.62604	37
.57159	1.33422	.58743	1.42380	.60339	1.52134	.61947	1.62790	38
.57185	1.33565	.58769	1.42536	.60365	1.52304	.61974	1.62976	39
.57212	1.33708	.58796	1.42692	.60392	1.52474	.62001	1.63162	40
.57238	1.33852	.58822	1.42848	.60419	1.52645	.62027	1.63348	41
.57264	1.33996	.58849	1.43005	.60445	1.52815	.62054	1.63535	42
.57291	1.34140	.58875	1.43162	.60472	1.52986	.62081	1.63722	43
.57317	1.34284	.58902	1.43318	.60499	1.53157	.62108	1.63909	44
.57343	1.34429	.58928	1.43476	.60526	1.53329	.62135	1.64097	45
.57369	1.34573	.58955	1.43633	.60552	1.53500	.62162	1.64285	46
.57396	1.34718	.58981	1.43790	.60579	1.53672	.62189	1.64473	47
.57422	1.34863	.59008	1.43948	.60606	1.53845	.62216	1.64662	48
.57448	1.35009	.59034	1.44106	.60633	1.54017	.62243	1.64851	49
.57475	1.35154	.59061	1.44264	.60659	1.54190	.62270	1.65040	50
.57501	1.35300	.59087	1.44423	.60686	1.54363	.62297	1.65229	51
.57527	1.35446	.59114	1.44582	.60713	1.54536	.62324	1.65419	52
.57554	1.35592	.59140	1.44741	.60740	1.54709	.62351	1.65609	53
.57580	1.35738	.59167	1.44900	.60766	1.54883	.62378	1.65799	54
.57606	1.35885	.59194	1.45059	.60793	1.55057	.62405	1.65989	55
.57633	1.36031	.59220	1.45219	.60820	1.55231	.62431	1.66180	56
.57659	1.36178	.59247	1.45378	.60847	1.55405	.62458	1.66371	57
.57685	1.36325	.59273	1.45539	.60873	1.55580	.62485	1.66563	58
.57712	1.36473	.59300	1.45699	.60900	1.55755	.62512	1.66755	59
.57738	1.36620	.59326	1.45859	.60927	1.55930	.62539	1.66947	60

′	68°		69°		70°		71°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.62539	1.66947	.64163	1.79043	.65798	1.92380	.67443	2.07155	0
1	.62566	1.67139	.64190	1.79254	.65825	1.92614	.67471	2.07415	1
2	.62593	1.67332	.64218	1.79466	.65853	1.92849	.67498	2.07675	2
3	.62620	1.67525	.64245	1.79679	.65880	1.93083	.67526	2.07936	3
4	.62647	1.67718	.64272	1.79891	.65907	1.93318	.67553	2.08197	4
5	.62674	1.67911	.64299	1.80104	.65935	1.93554	.67581	2.08459	5
6	.62701	1.68105	.64326	1.80318	.65962	1.93790	.67608	2.08721	6
7	.62728	1.68299	.64353	1.80531	.65989	1.94026	.67636	2 08983	7
8	.62755	1.68494	.64381	1.80746	.66017	1.94263	.67663	2 09246	8
9	.62782	1.68689	.64408	1.80960	.66044	1.94500	.67691	2 09510	9
10	.62809	1.68884	.64435	1.81175	.66071	1.94737	67718	2.09774	10
11	.62836	1 69079	.64462	1.81390	.66099	1.94975	.67746	2.10038	11
12	.62863	1.69275	.64489	1.81605	.66126	1.95213	.67773	2.10303	12
13	.62890	1.69471	.64517	1.81821	.66154	1.95452	.67801	2.10568	13
14	.62917	1.69667	.64544	1.82037	.66181	1.95691	.67829	2.10834	14
15	.62944	1.69864	.64571	1.82254	.66208	1.95931	.67856	2.11101	15
16	.62971	1.70061	.64598	1.82471	.66236	1.96171	.67884	2.11367	16
17	62998	1.70258	.64625	1.82688	.66263	1.96411	.67911	2.11635	17
18	.63025	1.70455	.64653	1.82906	.66290	1.96652	.67939	2.11903	18
19	.63052	1.70653	.64680	1.83124	.66318	1.96893	.67966	2.12171	19
20	.63079	1.70851	.64707	1.83342	.66345	1.97135	.67994	2.12440	20
21	.63106	1.71050	.64734	1.83561	.66373	1.97377	.68021	2.12709	21
22	.63133	1.71249	.64761	1.83780	.66400	1.97619	.68049	2.12979	22
23	.63161	1.71448	.64789	1.83999	.66427	1.97862	.68077	2.13249	23
24	.63188	1.71647	.64816	1.84219	.66455	1.98106	.68104	2.13520	24
25	.63215	1.71847	.64843	1.84439	.66482	1.98349	.68132	2.13791	25
26	.63242	1.72047	.64870	1.84659	.66510	1.98594	.68159	2.14063	26
27	.63269	1.72247	.64898	1.84880	.66537	1.98838	.68187	2.14335	27
28	.63296	1.72448	.64925	1.85102	.66564	1.99083	.68214	2.14608	28
29	.63323	1.72649	.64952	1.85323	.66592	1.99329	.68242	2.14881	29
30	.63350	1.72850	.64979	1.85545	.66619	1.99574	.68270	2.15155	30
31	.63377	1.73052	.65007	1.85767	.66647	1.99821	.68297	2.15429	31
32	.63404	1.73254	.65034	1.85990	.66674	2.00067	.68325	2.15704	32
33	.63431	1.73456	.65061	1.86213	.66702	2.00315	.68352	2.15979	33
34	.63458	1.73659	.65088	1.86437	.66729	2.00562	.68380	2.16255	34
35	.63485	1.73862	65116	1.86661	.66756	2 00810	.68408	2.16531	35
36	.63512	1.74065	.65143	1.86885	.66784	2.01059	.68435	2.16808	36
37	.63539	1.74269	.65170	1.87109	.66811	2.01308	68463	2.17085	37
38	.63566	1.74473	.65197	1.87334	.66839	2.01557	.68490	2.17363	38
39	.63594	1.74677	.65225	1.87560	.66866	2.01807	.68518	2.17641	39
40	.63621	1.74881	.65252	1.87785	.66894	2.02057	.68546	2.17920	40
41	.63648	1.75086	.65279	1.88011	.66921	2.02308	.68573	2 18199	41
42	.63675	1.75292	.65306	1.88238	.66949	2.02559	.68601	2.18479	42
43	.63702	1.75497	.65334	1.88465	.66976	2.02810	.68628	2.18759	43
44	.63729	1.75703	.65361	1.88692	.67003	2.03062	.68656	2.19040	44
45	.63756	1.75909	.65388	1.88920	.67031	2.03315	.68684	2.19322	45
46	.63783	1.76116	.65416	1.89148	.67058	2.03568	68711	2 19604	46
47	.63810	1.76323	.65443	1.89376	.67086	2.03821	.68739	2.19886	47
48	.63838	1.76530	.65470	1.89605	.67113	2.04075	.68767	2 20169	48
49	.63865	1.76737	.65497	1.89834	.67141	2.04329	.68794	2.20453	49
50	.63892	1.76945	.65525	1.90063	.67168	2.04584	.68822	2.20737	50
51	.63919	1.77154	.65552	1.90293	.67196	2.04839	.68849	2.21021	51
52	.63946	1.77362	.65579	1.90524	.67223	2.05094	.68877	2.21306	52
53	.63973	1.77571	.65607	1.90754	.67251	2.05350	.68905	2.21592	53
54	.64000	1 77780	.65634	1.90986	.67278	2.05607	.68932	2 21878	54
55	64027	1.77990	.65661	1.91217	.67306	2.05864	.68960	2.22165	55
56	.64055	1.78200	.65689	1.91449	.67333	2.06121	.68988	2.22452	56
57	64082	1.78410	.65716	1.91681	.67361	2.06379	.69015	2.22740	57
58	.64109	1.78621	.65743	1.91914	.67388	2.06637	69043	2 23028	58
9	.64136	1.78832	.65771	1.92147	.67416	2.06896	69071	2.23317	
	.64163	1.79043	.65798	1.92380	.67443	2.07155	.69098	2.23607	

′	72° Vers.	72° Ex. sec.	73° Vers.	73° Ex. sec.	74° Vers.	74° Ex. sec.	75° Vers.	75° Ex. sec.	′
0	.69098	2.23607	.70763	2.42030	.72436	2.62796	.74118	2.86370	0
1	.69126	2.23897	.70791	2.42356	.72464	2.63164	.74146	2.86790	1
2	.69154	2.24187	.70818	2.42683	.72492	2.63533	.74174	2.87211	2
3	.69181	2.24478	.70846	2.43010	.72520	2.63903	.74202	2.87633	3
4	.69209	2.24770	.70874	2.43337	.72548	2.64274	.74231	2.88056	4
5	.69237	2.25062	.70902	2.43666	.72576	2.64645	.74259	2.88479	5
6	.69264	2.25355	.70930	2.43995	.72604	2.65018	.74287	2.88904	6
7	.69292	2.25648	.70958	2.44324	.72632	2.65391	.74315	2.89330	7
8	.69320	2.25942	.70985	2.44655	.72660	2.65765	.74343	2.89756	8
9	.69347	2.26237	.71013	2.44986	.72688	2.66140	.74371	2.90184	9
10	.69375	2.26531	.71041	2.45317	.72716	2.66515	.74399	2.90613	10
11	.69403	2.26827	.71069	2.45650	.72744	2.66892	.74427	2.91042	11
12	.69430	2.27123	.71097	2.45983	.72772	2.67269	.74455	2.91473	12
13	.69458	2.27420	.71125	2.46316	.72800	2.67647	.74484	2.91904	13
14	.69486	2.27717	.71153	2.46651	.72828	2.68025	.74512	2.92337	14
15	.69514	2.28015	.71180	2.46986	.72856	2.68405	.74540	2.92770	15
16	.69541	2.28313	.71208	2.47321	.72884	2.68785	.74568	2.93204	16
17	.69569	2.28612	.71236	2.47658	.72912	2.69167	.74596	2.93640	17
18	.69597	2.28912	.71264	2.47995	.72940	2.69549	.74624	2.94076	18
19	.69624	2.29212	.71292	2.48333	.72968	2.69931	.74652	2.94514	19
20	.69652	2.29512	.71320	2.48671	.72996	2.70315	.74680	2.94952	20
21	.69680	2.29814	.71348	2.49010	.73024	2.70700	.74709	2.95392	21
22	.69708	2.30115	.71375	2.49350	.73052	2.71085	.74737	2.95832	22
23	.69735	2.30418	.71403	2.49691	.73080	2.71471	.74765	2.96274	23
24	.69763	2.30721	.71431	2.50032	.73108	2.71858	.74793	2.96716	24
25	.69791	2.31024	.71459	2.50374	.73136	2.72246	.74821	2.97160	25
26	.69818	2.31328	.71487	2.50716	.73164	2.72635	.74849	2.97604	26
27	.69846	2.31633	.71515	2.51060	.73192	2.73024	.74878	2.98050	27
28	.69874	2.31939	.71543	2.51404	.73220	2.73414	.74906	2.98497	28
29	.69902	2.32244	.71571	2.51748	.73248	2.73806	.74934	2.98944	29
30	.69929	2.32551	.71598	2.52094	.73276	2.74198	.74962	2.99393	30
31	.69957	2.32858	.71626	2.52440	.73304	2.74591	.74990	2.99843	31
32	.69985	2.33166	.71654	2.52787	.73332	2.74984	.75018	3.00293	32
33	.70013	2.33474	.71682	2.53134	.73360	2.75379	.75047	3.00745	33
34	.70040	2.33783	.71710	2.53482	.73388	2.75775	.75075	3.01198	34
35	.70068	2.34092	.71738	2.53831	.73416	2.76171	.75103	3.01652	35
36	.70096	2.34403	.71766	2.54181	.73444	2.76568	.75131	3.02107	36
37	.70124	2.34713	.71794	2.54531	.73472	2.76966	.75159	3.02563	37
38	.70151	2.35025	.71822	2.54883	.73500	2.77365	.75187	3.03020	38
39	.70179	2.35336	.71850	2.55235	.73529	2.77765	.75216	3.03479	39
40	.70207	2.35649	.71877	2.55587	.73557	2.78166	.75244	3.03938	40
41	.70235	2.35962	.71905	2.55940	.73585	2.78568	.75272	3.04398	41
42	.70263	2.36276	.71933	2.56294	.73613	2.78970	.75300	3.04860	42
43	.70290	2.36590	.71961	2.56649	.73641	2.79374	.75328	3.05322	43
44	.70318	2.36905	.71989	2.57005	.73669	2.79778	.75356	3.05786	44
45	.70346	2.37221	.72017	2.57361	.73697	2.80183	.75385	3.06251	45
46	.70374	2.37537	.72045	2.57718	.73725	2.80589	.75413	3.06717	46
47	.70401	2.37854	.72073	2.58076	.73753	2.80996	.75441	3.07184	47
48	.70429	2.38171	.72101	2.58434	.73781	2.81404	.75469	3.07652	48
49	.70457	2.38489	.72129	2.58794	.73809	2.81813	.75497	3.08121	49
50	.70485	2.38808	.72157	2.59154	.73837	2.82223	.75526	3.08591	50
51	.70513	2.39128	.72185	2.59514	.73865	2.82633	.75554	3.09063	51
52	.70540	2.39448	.72213	2.59876	.73893	2.83045	.75582	3.09535	52
53	.70568	2.39768	.72241	2.60238	.73921	2.83457	.75610	3.10009	53
54	.70596	2.40089	.72269	2.60601	.73950	2.83871	.75639	3.10484	54
55	.70624	2.40411	.72296	2.60965	.73978	2.84285	.75667	3.10960	55
56	.70652	2.40734	.72324	2.61330	.74006	2.84700	.75695	3.11437	56
57	.70679	2.41057	.72352	2.61695	.74034	2.85116	.75723	3.11915	5
58	.70707	2.41381	.72380	2.62061	.74062	2.85533	.75751	3.12394	
59	.70735	2.41705	.72408	2.62428	.74090	2.85951	.75780	3.12875	
60	.70763	2.42030	.72436	2.62796	.74118	2.86370	.75808	3	

′	76°		77°		78°		79°	
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	E
0	.75808	3.13357	.77505	3.44541	.79209	3.80973	.80919	4
1	.75836	3.13839	.77533	3.45102	.79237	3.81633	.80948	4
2	.75864	3.14323	.77562	3.45664	.79266	3.82294	.80976	4
3	.75892	3.14809	.77590	3.46228	.79294	3.82956	.81005	4
4	.75921	3.15295	.77618	3.46793	.79323	3.83621	.81033	4
5	.75949	3.15782	.77647	3.47360	.79351	3.84288	.81062	4
6	.75977	3.16271	.77675	3.47928	.79380	3.84956	.81090	4
7	.76005	3.16761	.77703	3.48498	.79408	3.85627	.81119	4
8	.76034	3.17252	.77732	3.49069	.79437	3.86299	.81148	4
9	.76062	3.17744	.77760	3.49642	.79465	3.86973	.81176	4
10	.76090	3.18238	.77788	3.50216	.79493	3.87649	.81205	4
11	.76118	3.18733	.77817	3.50791	.79522	3.88327	.81233	4
12	.76147	3.19228	.77845	3.51368	.79550	3.89007	.81262	4
13	.76175	3.19725	.77874	3.51947	.79579	3.89689	.81290	4
14	.76203	3.20224	.77902	3.52527	.79607	3.90373	.81319	4
15	.76231	3.20723	.77930	3.53109	.79636	3.91058	.81348	4
16	.76260	3.21224	.77959	3.53692	.79664	3.91746	.81376	4
17	.76288	3.21726	.77987	3.54277	.79693	3.92436	.81405	4
18	.76316	3.22229	.78015	3.54863	.79721	3.93128	.81433	4
19	.76344	3.22734	.78044	3.55451	.79750	3.93821	.81462	4
20	.76373	3.23239	.78072	3.56041	.79778	3.94517	.81491	4
21	.76401	3.23746	.78101	3.56632	.79807	3.95215	.81519	4
22	.76429	3.24255	.78129	3.57224	.79835	3.95914	.81548	4
23	.76458	3.24764	.78157	3.57819	79864	3.96616	.81576	4
24	.76486	3.25275	.78186	3.58414	.79892	3.97320	.81605	4
25	.76514	3.25787	.78214	3.59012	.79921	3.98025	.81633	4
26	.76542	3.26300	.78242	3.59611	.79949	3.98733	.81662	4
27	.76571	3.26814	.78271	3.60211	.79978	3.99443	.81691	4
28	.76599	3.27330	.78299	3.60813	.80006	4.00155	.81719	4
29	.76627	3.27847	.78328	3.61417	.80035	4.00869	.81748	4
30	.76655	3.28366	.78356	3.62023	.80063	4.01585	.81776	4
31	.76684	3.28885	.78384	3.62630	.80092	4.02303	.81805	4
32	.76712	3.29406	.78413	3.63238	.80120	4.03024	.81834	4
33	.76740	3.29929	.78441	3 63849	.80149	4.03746	.81862	4
34	.76769	3.30452	.78470	3.64461	.80177	4.04471	.81891	4.
35	.76797	3.30977	.78498	3.65074	.80206	4.05197	.81919	4.
36	.76825	3.31503	.78526	3.65690	.80234	4.05926	.81948	4
37	.76854	3.32031	.78555	3.66307	.80263	4.06657	.81977	4.
38	.76882	3.32560	.78583	3.66925	.80291	4.07390	.82005	4.
39	.76910	3.33090	.78612	3.67545	.80320	4.08125	.82034	4.
40	.76938	3.33622	.78640	3.68167	.80348	4.08863	.82063	4.
41	.76967	3.34154	.78669	3.68791	.80377	4.09602	.82091	4.
42	.76995	3.34689	.78697	3.69417	.80405	4.10344	.82120	4.
43	.77023	3.35224	.78725	3.70014	.80434	4.11088	.82148	4.
44	.77052	3.35761	.78754	3.70673	.80462	4.11835	.82177	4.
45	.77080	3.36299	.78782	3.71303	.80491	4.12583	.82206	4.
46	.77108	3.36839	.78811	3.71935	.80520	4.13334	.82234	4.
47	.77137	3.37380	.78839	3.72569	.80548	4.14087	.82263	4.
48	.77165	3.37923	.78868	3.73205	.80577	4.14842	.82292	4.
49	.77193	3.38466	.78896	3.73843	.80605	4.15599	.82320	4.
50	.77222	3.39012	.78924	3.74482	.80634	4.16359	.82349	4.
51	.77250	3.39558	.78953	3.75123	.80662	4.17121	.82377	4.
52	.77278	3.40106	.78981	3.75766	.80691	4.17886	.82406	4.
53	.77307	3.40656	.79010	3.76411	.80719	4.18652	.82435	4.
54	.77335	3.41206	.79038	3.77057	.80748	4.19421	.82463	4.
55	.77363	3.41759	.79067	3.77705	.80776	4.20193	.82492	4.
[illegible]	.77392	3.42312	.79095	3.78355	.80805	4.20966	.82521	4.
[illegible]	[illegible]7420	3.42867	.79123	3.79007	.80833	4.21742	.82549	4
[illegible]	[illegible]448	3.43424	.79152	3.79661	.80862	4.22521	.82578	
[illegible]	[illegible]77	3.43982	.79180	3.80316	.80891	4.23301	.82607	
[illegible]	[illegible]	3.44541	.79209	3.80973	.80919	4.24084	.82635	

′	80°		81°		82°		83°		′
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.82635	4.75877	.84357	5.39245	.86083	6.18530	.87813	7.20551	0
1	.82664	4.76829	.84385	5.40422	.86112	6.20020	.87842	7.22500	1
2	.82692	4.77784	.84414	5.41602	.86140	6.21517	.87871	7.24457	2
3	.82721	4.78742	.84443	5.42787	.86169	6.23019	.87900	7.26425	3
4	.82750	4.79703	.84471	5.43977	.86198	6.24529	.87929	7.28402	4
5	.82778	4.80667	.84500	5.45171	.86227	6.26044	.87957	7.30388	5
6	.82807	4.81635	.84529	5.46369	.86256	6.27566	.87986	7.32384	6
7	.82836	4.82606	.84558	5.47572	.86284	6.29095	.88015	7.34390	7
8	.82864	4.83581	.84586	5.48779	.86313	6.30630	.88044	7.36405	8
9	.82893	4.84558	.84615	5.49991	.86342	6.32171	.88073	7.38431	9
10	.82922	4.85539	.84644	5.51208	.86371	6.33719	.88102	7.40466	10
11	.82950	4.86524	.84673	5.52429	.86400	6.35274	.88131	7.42511	11
12	.82979	4.87511	.84701	5.53655	.86428	6.36835	.88160	7.44566	12
13	.83008	4.88502	.84730	5.54886	.86457	6.38403	.88188	7.46632	13
14	.83036	4.89497	.84759	5.56121	.86486	6.39978	.88217	7.48707	14
15	.83065	4.90495	.84788	5.57361	.86515	6.41560	.88246	7.50793	15
16	.83094	4.91496	.84816	5.58606	.86544	6.43148	.88275	7.52889	16
17	.83122	4.92501	.84845	5.59855	.86573	6.44743	.88304	7.54996	17
18	.83151	4.93509	.84874	5.61110	.86601	6.46346	.88333	7.57113	18
19	.83180	4.94521	.84903	5.62369	.86630	6.47955	.88362	7.59241	19
20	.83208	4.95536	.84931	5.63633	.86659	6.49571	.88391	7.61379	20
21	.83237	4.96555	.84960	5.64902	.86688	6.51194	.88420	7.63528	21
22	.83266	4.97577	.84989	5 66176	.86717	6.52825	.88448	7.65688	22
23	.83294	4.98603	.85018	5.67454	.86746	6.54462	.88477	7.67859	23
24	.83323	4.99633	.85046	5.68738	.86774	6.56107	.88506	7.70041	24
25	.83352	5.00666	.85075	5.70027	.86803	6.57759	.88535	7.72234	25
26	.83380	5.01703	.85104	5.71321	.86832	6.59418	.88564	7.74438	26
27	.83409	5.02743	.85133	5.72620	.86861	6.61085	.88593	7.76653	27
28	.83438	5.03787	.85162	5.73924	.86890	6.62759	.88622	7.78880	28
29	.83467	5.04834	.85190	5.75233	.86919	6.64441	.88651	7.81118	29
30	.83495	5.05886	.85219	5.76547	.86947	6.66130	.88680	7.83367	30
31	.83524	5.06941	.85248	5.77866	.86976	6.67826	.88709	7.85628	31
32	.83553	5.08000	.85277	5.79191	.87005	6.69530	.88737	7.87901	32
33	.83581	5.09062	.85305	5.80521	.87034	6.71242	.88766	7.90186	33
34	.83610	5.10129	.85334	5.81856	.87063	6.72962	.88795	7.92482	34
35	.83639	5.11199	.85363	5.83196	.87092	6.74689	.88824	7.94791	35
36	.83667	5.12273	.85392	5.84542	.87120	6.76424	.88853	7.97111	36
37	.83696	5.13350	.85420	5.85893	.87149	6.78167	.88882	7.99444	37
38	.83725	5.14432	.85449	5.87250	.87178	6.79918	.88911	8.01788	38
39	.83754	5.15517	.85478	5.88612	.87207	6.81677	.88940	8.04146	39
40	.83782	5.16607	.85507	5.89979	.87236	6.83443	.88969	8.06515	40
41	.83811	5.17700	.85536	5.91352	.87265	6.85218	.88998	8.08897	41
42	.83840	5.18797	.85564	5.92731	.87294	6.87001	.89027	8.11292	42
43	.83868	5.19898	.85593	5.94115	.87322	6.88792	.89055	8.13699	43
44	.83897	5.21004	.85622	5.95505	.87351	6.90592	.89084	8.16120	44
45	.83926	5.22113	.85651	5.96900	.87380	6.92400	.89113	8.18553	45
46	.83954	5.23226	.85680	5.98301	.87409	6.94216	.89142	8.20999	46
47	.83983	5.24343	.85708	5.99708	.87438	6.96040	.89171	8.23459	47
48	.84012	5.25464	.85737	6.01120	.87467	6.97873	.89200	8.25931	48
49	.84041	5.26590	.85766	6.02538	.87496	6.99714	.89229	8.28417	49
50	.84069	5.27719	.85795	6.03962	.87524	7.01565	.89258	8.30917	50
51	.84098	5.28853	.85823	6.05392	.87553	7.03423	.89287	8.33430	51
52	.84127	5.29991	.85852	6.06828	.87582	7.05291	.89316	8.35957	52
53	.84155	5.31133	.85881	6.08269	.87611	7.07167	.89345	8.38497	53
54	.84184	5.32279	.85910	6.09717	.87640	7.09052	.89374	8.41052	54
55	.84213	5.33429	.85939	6.11171	.87669	7.10946	.89403	8.43620	55
56	.84242	5.34584	.85967	6.12630	.87698	7.12849	.89431	8.46208	
57	.84270	5.35743	.85996	6.14096	.87726	7.14760	.89460	8.48800	
58	.84299	5.36906	.86025	6.15568	.87755	7.16681	.89489	8.51411	
9	.84328	5.38073	.86054	6.17046	.87784	7.18612	.89518	8.540	
0	.84357	5.39245	.86083	6.18530	.87813	7.20551	.89547	8	

′	84°		85°		86°		
	Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
0	.89547	8.56677	.91284	10.47371	.93024	13.33559	0
1	.89576	8.59332	.91313	10.51199	.93053	13.39547	1
2	.89605	8.62002	.91342	10.55052	.93082	13.45586	2
3	.89634	8.64687	.91371	10.58932	.93111	13.51676	3
4	.89663	8.67387	.91400	10.62837	.93140	13.57817	4
5	.89692	8.70103	.91429	10.66769	.93169	13.64011	5
6	.89721	8.72833	.91458	10.70728	.93198	13.70258	6
7	.89750	8.75579	.91487	10.74714	.93227	13.76558	7
8	.89779	8.78341	.91516	10.78727	.93257	13.82913	8
9	.89808	8.81119	.91545	10.82768	.93286	13.89323	9
10	.89836	8.83912	.91574	10.86837	.93315	13.95788	10
11	.89865	8.86722	.91603	10.90934	.93344	14.02310	11
12	.89894	8.89547	.91632	10.95060	.93373	14.08890	12
13	.89923	8.92389	.91661	10.99214	.93402	14.15527	13
14	.89952	8.95248	.91690	11.03397	.93431	14.22223	14
15	.89981	8.98123	.91719	11.07610	.93460	14.28979	15
16	.90010	9.01015	.91748	11.11852	.93489	14.35795	16
17	.90039	9.03923	.91777	11.16125	.93518	14.42672	17
18	.90068	9.06849	.91806	11.20427	.93547	14.49611	18
19	.90097	9.09792	.91835	11.24761	.93576	14.56614	19
20	.90126	9.12752	.91864	11.29125	.93605	14.63679	20
21	.90155	9.15730	.91893	11.33521	.93634	14.70810	21
22	.90184	9.18725	.91922	11.37948	.93663	14.78005	22
23	.90213	9.21739	.91951	11.42408	.93692	14.85268	23
24	.90242	9.24770	.91980	11.46900	.93721	14.92597	24
25	.90271	9.27819	.92009	11.51424	.93750	14.99995	25
26	.90300	9.30887	.92038	11.55982	.93779	15.07462	26
27	.90329	9.33973	.92067	11.60572	.93808	15.14999	27
28	.90358	9.37077	.92096	11.65197	.93837	15.22607	28
29	.90386	9.40201	.92125	11.69856	.93866	15.30287	29
30	.90415	9.43343	.92154	11.74550	.93895	15.38041	30
31	.90444	9.46505	.92183	11.79278	.93924	15.45869	31
32	.90473	9.49685	.92212	11.84042	.93953	15.53772	32
33	.90502	9.52886	.92241	11.88841	.93982	15.61751	33
34	.90531	9.56106	.92270	11.93677	.94011	15.69808	34
35	.90560	9.59346	.92299	11.98549	.94040	15.77944	35
36	.90589	9.62605	.92328	12.03458	.94069	15.86159	36
37	.90618	9.65885	.92357	12.08404	.94098	15.94456	37
38	.90647	9.69186	.92386	12.13388	.94127	16.02835	38
39	.90676	9.72507	.92415	12.18411	.94156	16.11297	39
40	.90705	9.75849	.92444	12.23472	.94186	16.19843	40
41	.90734	9.79212	.92473	12.28572	.94215	16.28476	41
42	.90763	9.82596	.92502	12.33712	.94244	16.37196	42
43	.90792	9.86001	.92531	12.38891	.94273	16.46005	43
44	.90821	9.89428	.92560	12.44112	.94302	16.54903	44
45	.90850	9.92877	.92589	12.49373	.94331	16.63893	45
46	.90879	9.96348	.92618	12.54676	.94360	16.72975	46
47	.90908	9.99841	.92647	12.60021	.94389	16.82152	47
48	.90937	10.03356	.92676	12.65408	.94418	16.91424	48
49	.90966	10.06894	.92705	12.70838	.94447	17.00794	49
50	.90995	10.10455	.92734	12.76312	.94476	17.10262	50
51	.91024	10.14039	.92763	12.81829	.94505	17.19830	51
52	.91053	10.17646	.92792	12.87391	.94534	17.29501	52
53	.91082	10.21277	.92821	12.92999	.94563	17.39274	53
54	.91111	10.24932	.92850	12.98651	.94592	17.49153	54
55	91140	10.28610	.92879	13 04350	.94621	17.59139	55
56	.91169	10.32313	.92908	13.10096	.94650	17.69233	56
57	.91197	10.36040	.92937	13.15889	.94679	17.79438	57
58	.91226	10.39792	.92966	13.21730	.94708	17.89755	58
59	.91255	10.43569	.92995	13.27620	.94737	18.00185	59
60	.91284	10.47371	.93024	13.33559	.94766	18.10732	60

87°		88°		89°		′
Vers.	Ex. sec.	Vers.	Ex. sec.	Vers.	Ex. sec.	
.94766	18.10732	.96510	27.65371	.98255	56.29869	0
.94795	18.21397	.96539	27.89440	.98284	57.26976	1
.94825	18.32182	.96568	28.13917	.98313	58.27431	2
.94854	18.43088	.96597	28.38812	.98342	59.31411	3
.94883	18.54119	.96626	28.64137	.98371	60.39105	4
.94912	18.65275	.96655	28.89903	.98400	61.50715	5
.94941	18.76560	.96684	29.16120	.98429	62.66460	6
.94970	18.87976	.96714	29.42802	.98458	63.86572	7
.94999	18.99524	.96743	29.69960	.98487	65.11304	8
.95028	19.11208	.96772	29.97607	.98517	66.40927	9
.95057	19.23028	.96801	30.25758	.98546	67.75736	10
.95086	19.34989	.96830	30.54425	.98575	69.16047	11
.95115	19.47093	.96859	30.83623	.98604	70.62205	12
.95144	19.59341	.96888	31.13366	.98633	72.14583	13
.95173	19.71737	.96917	31.43671	.98662	73.73586	14
.95202	19.84283	.96946	31.74554	.98691	75.39655	15
.95231	19.96982	.96975	32.06030	.98720	77.13274	16
.95260	20.09838	.97004	32.38118	.98749	78.94908	17
.95289	20.22852	.97033	32.70835	.98778	80.85315	18
.95318	20.36027	.97062	33.04199	.98807	82.84947	19
.95347	20.49368	.97092	33.38232	.98836	84.94561	20
.95377	20.62876	.97121	33.72952	.98866	87.14924	21
.95406	20.76555	.97150	34.08380	.98895	89.46886	22
.95435	20.90409	.97179	34.44539	.98924	91.91387	23
.95464	21.04440	.97208	34.81452	.98953	94.49471	24
.95493	21.18653	.97237	35.19141	.98982	97.22303	25
.95522	21.33050	.97266	35.57633	.99011	100.1119	26
.95551	21.47635	.97295	35.96953	.99040	103.1757	27
.95580	21.62413	.97324	36.37127	.99069	106.4311	28
.95609	21.77386	.97353	36.78185	.99098	109.8966	29
.95638	21.92559	.97382	37.20155	.99127	113.5930	30
.95667	22.07935	.97411	37.63068	.99156	117.5444	31
.95696	22.23520	.97440	38.06957	.99186	121.7780	32
.95725	22.39316	.97470	38.51855	.99215	126.3253	33
.95754	22.55329	.97499	38.97797	.99244	131.2223	34
.95783	22.71563	.97528	39.44820	.99273	136.5111	35
.95812	22.88022	.97557	39.92963	.99302	142.2406	36
.95842	23.04712	.97586	40.42266	.99331	148.4684	37
.95871	23.21637	.97615	40.92772	.99360	155.2623	38
.95900	23.38802	.97644	41.44525	.99389	162.7033	39
.95929	23.56212	.97673	41.97571	.99418	170.8883	40
.95958	23.73873	.97702	42.51961	.99447	179.9350	41
.95987	23.91790	.97731	43.07746	.99476	189.9868	42
.96016	24.09969	.97760	43.64980	.99505	201.2212	43
.96045	24.28414	.97789	44.23720	.99535	213.8600	44
.96074	24.47134	.97819	44.84026	.99564	228.1839	45
.96103	24.66132	.97848	45.45963	.99593	244.5540	46
.96132	24.85417	.97877	46.09596	.99622	263.4427	47
.96161	25.04994	.97906	46.74997	.99651	285.4795	48
.96190	25.24869	.97935	47.42241	.99680	311.5230	49
.96219	25.45051	.97964	48.11406	.99709	342.7752	50
.96248	25.65546	.97993	48.82576	.99738	380.9723	51
.96277	25.86360	.98022	49.55840	.99767	428.7187	52
.96307	26.07503	.98051	50.31290	.99796	490.1070	53
.96336	26.28981	.98080	51.09027	.99825	571.9581	54
.96365	26.50804	.98109	51.89156	.99855	686.5496	55
.96394	26.72978	.98138	52.71790	.99884	858.4369	56
.96423	26.95513	.98168	53.57046	.99913	1144.916	57
.96452	27.18417	.98197	54.45053	.99942	1717.874	58
.96481	27.41700	.98226	55.35946	.99971	3437.747	59
.96510	27.65371	.98255	56.29869	1.00000	Infinite	60

Depth d	Base 12	Base 14	Base 16	Base 18	Base 22	Base 24	Base 26	Base 28
1	45	53	60	68	82	90	97	105
2	93	107	122	137	167	181	196	211
3	142	163	186	208	253	275	297	319
4	193	222	252	281	341	370	400	430
5	245	282	319	356	431	468	505	542
6	300	344	389	433	522	567	611	656
7	356	408	460	512	616	668	719	771
8	415	474	533	593	711	770	830	889
9	475	542	608	675	808	875	942	1008
10	537	611	685	759	907	981	1056	1130
11	601	682	764	845	1008	1090	1171	1253
12	667	756	844	933	1111	1200	1289	1378
13	734	831	926	1023	1216	1312	1408	1505
14	804	907	1010	1115	1322	1426	1530	1633
15	875	986	1096	1208	1431	1542	1653	1764
16	948	1067	1184	1304	1541	1659	1778	1896
17	1023	1149	1274	1401	1653	1779	1905	2031
18	1100	1233	1366	1500	1767	1900	2033	2167
19	1179	1319	1460	1601	1882	2023	2164	2305
20	1259	1407	1555	1704	2000	2148	2296	2444
21	1342	1497	1653	1808	2119	2275	2431	2586
22	1426	1589	1752	1915	2241	2404	2567	2730
23	1512	1682	1853	2023	2364	2534	2705	2875
24	1600	1778	1955	2133	2489	2667	2844	3022
25	1690	1875	2060	2245	2616	2801	2986	3171
26	1781	1974	2166	2359	2744	2937	3130	3322
27	1875	2075	2274	2475	2875	3075	3275	3475
28	1970	2178	2384	2593	3007	3215	3422	3630
29	2068	2282	2496	2712	3142	3356	3571	3786
30	2167	2389	2610	2833	3278	3500	3722	3944
31	2268	2497	2726	2956	3416	3645	3875	4105
32	2370	2607	2844	3081	3556	3793	4030	4267
33	2475	2719	2964	3208	3697	3942	4186	4431
34	2581	2833	3085	3337	3841	4093	4344	4596
35	2690	2949	3208	3468	3986	4245	4505	4764
36	2800	3067	3333	3600	4133	4400	4667	4933
37	2912	3186	3460	3734	4282	4556	4831	5105
38	3026	3307	3589	3870	4433	4715	4996	5278
39	3142	3431	3719	4008	4586	4875	5164	5453
40	3259	3556	3852	4148	4741	5037	5333	5630
41	3379	3682	3986	4290	4897	5201	5505	5808
42	3500	3811	4122	4433	5056	5367	5678	5989
43	3623	3942	4260	4579	5216	5534	5853	6171
44	3748	4074	4400	4726	5378	5704	6030	6356
45	3875	4208	4541	4875	5542	5875	6208	6542
46	4004	4344	4684	5026	5707	6048	6389	6730
47	4134	4482	4830	5179	5875	6223	6571	6919
48	4267	4622	4978	5333	6044	6400	6756	7111
49	4401	4764	5127	5490	6216	6579	6942	7305
50	4537	4907	5278	5648	6389	6759	7130	7500
51	4675	5053	5430	5808	6564	6942	7319	7697
52	4815	5200	5584	5970	6741	7126	7511	7896
53	4956	5349	5741	6134	6919	7312	7705	8097
54	5100	5500	5900	6300	7100	7500	7900	8300
55	5245	5653	6060	6468	7282	7690	8097	8505
56	5393	5807	6222	6637	7467	7881	8296	8711
57	5542	5964	6386	6808	7653	8075	8497	8919
58	5693	6122	6552	6981	7841	8270	8700	9130
59	5845	6282	6719	7156	8031	8468	8905	9342
60	6000	6444	6889	7333	8222	8667	9111	9556

Depth d	Base 12	Base 14	Base 16	Base 18	Base 22	Base 24	Base 26	Base 28
1	46	54	61	69	83	91	98	106
2	96	111	126	141	170	185	200	215
3	150	172	194	217	261	283	306	328
4	207	237	267	296	356	385	415	444
5	269	306	343	380	454	491	528	565
6	333	378	422	467	556	600	644	689
7	402	454	506	557	661	713	765	817
8	474	533	593	652	770	830	889	948
9	550	617	683	750	883	950	1017	1083
10	630	704	778	852	1000	1074	1148	1222
11	713	794	876	957	1120	1202	1283	1365
12	800	889	978	1067	1244	1333	1422	1511
13	891	987	1083	1180	1372	1469	1565	1661
14	985	1089	1193	1296	1504	1607	1711	1815
15	1083	1194	1306	1417	1639	1750	1861	1972
16	1185	1304	1422	1541	1779	1896	2015	2133
17	1291	1417	1543	1669	1920	2046	2172	2298
18	1400	1533	1667	1800	2067	2200	2333	2467
19	1513	1654	1794	1935	2217	2357	2498	2639
20	1630	1778	1926	2074	2370	2519	2667	2815
21	1750	1906	2061	2217	2528	2683	2839	2994
22	1874	2037	2200	2363	2689	2852	3015	3178
23	2002	2172	2343	2513	2854	3024	3194	3365
24	2133	2311	2489	2667	3022	3200	3378	3556
25	2269	2454	2639	2824	3194	3380	3565	3750
26	2407	2600	2793	2985	3370	3563	3756	3948
27	2550	2750	2950	3150	3550	3750	3950	4151
28	2696	2904	3111	3319	3733	3941	4148	4356
29	2846	3061	3276	3491	3920	4135	4350	4565
30	3000	3222	3444	3667	4111	4333	4556	4778
31	3157	3387	3617	3846	4306	4535	4765	4994
32	3319	3556	3793	4030	4504	4741	4978	5215
33	3483	3728	3972	4217	4706	4950	5194	5439
34	3652	3904	4156	4407	4911	5163	5415	5667
35	3824	4083	4343	4602	5120	5380	5639	5898
36	4000	4267	4533	4800	5333	5600	5867	6133
37	4180	4454	4728	5002	5550	5824	6098	6372
38	4363	4644	4926	5207	5770	6052	6333	6615
39	4550	4839	5128	5417	5994	6283	6572	6861
40	4741	5037	5333	5630	6222	6519	6815	7111
41	4935	5239	5543	5846	6454	6757	7061	7365
42	5133	5444	5756	6067	6689	7000	7311	7622
43	5335	5654	5972	6291	6928	7246	7565	7883
44	5541	5867	6193	6519	7170	7496	7822	8148
45	5750	6083	6417	6750	7417	7750	8083	8417
46	5963	6304	6644	6985	7667	8007	8348	8689
47	6180	6528	6876	7224	7920	8269	8617	8965
48	6400	6756	7111	7467	8178	8533	8889	9244
49	6624	6987	7350	7713	8439	8802	9165	9528
50	6852	7222	7593	7963	8704	9074	9444	9815
51	7083	7461	7839	8217	8972	9350	9728	10106
52	7319	7704	8089	8474	9244	9630	10015	10400
53	7557	7960	8343	8735	9520	9913	10306	10698
54	7800	8200	8600	9000	9800	10200	10600	11000
55	8046	8454	8861	9269	10083	10491	10898	11306
56	8296	8711	9126	9541	10370	10785	11200	11615
57	8550	8972	9394	9817	10661	11083	11506	11928
58	8807	9237	9667	10096	10956	11385	11815	12244
59	9069	9506	9943	10380	11254	11691	12128	12565
60	9333	9778	10222	10667	11556	12000	12444	12889

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	48	56	63	70	78	107	115	122
2	104	119	133	148	163	222	237	252
3	167	189	211	233	256	344	367	389
4	237	267	296	326	356	474	504	533
5	315	352	389	426	463	611	648	685
6	400	444	489	533	578	756	800	844
7	493	544	596	648	700	907	959	1011
8	593	652	711	770	830	1067	1126	1185
9	700	767	833	900	967	1233	1300	1367
10	815	889	963	1037	1111	1407	1481	1556
11	937	1019	1100	1181	1263	1589	1670	1752
12	1067	1156	1244	1333	1422	1778	1867	1956
13	1204	1300	1396	1493	1589	1974	2070	2167
14	1348	1452	1556	1659	1763	2178	2281	2385
15	1500	1611	1722	1833	1944	2389	2500	2611
16	1659	1778	1896	2015	2133	2607	2726	2844
17	1826	1952	2078	2204	2330	2833	2959	3085
18	2000	2133	2267	2400	2533	3067	3200	3333
19	2181	2322	2463	2604	2744	3307	3448	3589
20	2370	2519	2667	2815	2963	3556	3704	3852
21	2567	2722	2878	3033	3189	3811	3967	4122
22	2770	2933	3096	3259	3422	4074	4237	4400
23	2981	3152	3322	3493	3663	4344	4515	4685
24	3200	3378	3556	3733	3911	4622	4800	4978
25	3426	3611	3796	3981	4167	4907	5093	5278
26	3659	3852	4044	4237	4430	5200	5393	5585
27	3900	4100	4300	4500	4700	5500	5700	5900
28	4148	4356	4563	4770	4978	5807	6015	6222
29	4404	4619	4833	5048	5263	6122	6337	6552
30	4667	4889	5111	5333	5556	6444	6667	6889
31	4937	5167	5396	5626	5856	6774	7004	7233
32	5215	5452	5689	5926	6163	7111	7348	7585
33	5500	5744	5989	6233	6478	7456	7700	7944
34	5793	6044	6296	6548	6800	7807	8059	8311
35	6093	6352	6611	6870	7130	8167	8426	8685
36	6400	6667	6933	7200	7467	8533	8800	9067
37	6715	6989	7263	7537	7811	8907	9181	9456
38	7037	7319	7600	7881	8163	9289	9570	9852
39	7367	7656	7944	8233	8522	9678	9967	10256
40	7704	8000	8296	8593	8889	10074	10370	10667
41	8048	8352	8656	8959	9263	10478	10781	11085
42	8400	8711	9022	9333	9644	10889	11200	11511
43	8759	9078	9396	9715	10033	11307	11626	11944
44	9126	9452	9778	10104	10430	11733	12059	12385
45	9500	9833	10167	10500	10833	12167	12500	12833
46	9881	10222	10563	10904	11244	12607	12948	13289
47	10270	10619	10967	11315	11663	13056	13404	13752
48	10667	11022	11378	11733	12089	13511	13867	14222
49	11070	11433	11796	12159	12522	13974	14337	14700
50	11481	11852	12222	12593	12963	14444	14815	15185
51	11900	12278	12656	13033	13411	14922	15300	15678
52	12326	12711	13096	13481	13867	15407	15793	16178
53	12759	13152	13544	13937	14330	15900	16293	16685
54	13200	13600	14000	14400	14800	16400	16800	17200
55	13648	14056	14463	14870	15278	16907	17315	17722
56	14104	14519	14933	15348	15763	17422	17837	18252
57	14567	14989	15411	15833	16256	17944	18367	18789
58	15037	15467	15896	16326	16756	18474	18904	19333
59	15515	15952	16389	16826	17263	19011	19448	19885
60	16000	16444	16889	17333	17778	19556	20000	20444

h	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
	49	56	64	71	79	108	116	123
	107	122	137	152	167	226	241	256
	175	197	219	242	264	353	375	397
	252	281	311	341	370	489	519	548
	338	375	412	449	486	634	671	708
	433	478	522	567	611	789	833	878
	538	590	642	694	745	953	1005	1056
	652	711	770	830	889	1126	1185	1244
	775	842	908	975	1042	1308	1375	1442
	907	981	1056	1130	1204	1500	1574	1648
	1049	1131	1212	1294	1375	1701	1782	1864
	1200	1289	1378	1467	1556	1911	2000	2089
	1360	1456	1553	1649	1745	2131	2227	2323
	1530	1633	1737	1841	1944	2359	2463	2567
	1708	1819	1931	2042	2153	2597	2708	2819
	1896	2015	2133	2252	2370	2844	2963	3081
	2094	2219	2345	2471	2597	3101	3227	3353
	2300	2433	2567	2700	2833	3367	3500	3633
	2516	2656	2797	2938	3079	3642	3782	3923
	2741	2889	3037	3185	3333	3926	4074	4222
	2975	3131	3286	3442	3597	4220	4375	4531
	3219	3381	3544	3707	3870	4522	4685	4848
	3471	3642	3812	3982	4153	4834	5005	5175
	3733	3911	4089	4267	4444	5156	5333	5511
	4005	4190	4375	4560	4745	5486	5671	5856
	4285	4478	4670	4863	5056	5826	6019	6211
	4575	4775	4975	5175	5375	6175	6375	6575
	4874	5081	5289	5496	5704	6533	6741	6948
	5182	5397	5612	5827	6042	6901	7116	7331
	5500	5722	5944	6167	6389	7278	7500	7722
	5827	6056	6286	6516	6745	7664	7894	8123
	6163	6400	6637	6874	7111	8059	8296	8533
	6508	6753	6997	7242	7486	8464	8708	8953
	6863	7115	7367	7619	7870	8878	9130	9381
	7227	7486	7745	8005	8264	9301	9560	9819
	7600	7867	8133	8400	8667	9733	10000	10267
	7982	8256	8531	8805	9079	10175	10449	10723
	8374	8656	8937	9219	9500	10626	10907	11189
	8775	9064	9353	9642	9931	11086	11375	11664
	9185	9481	9778	10074	10370	11556	11852	12148
	9605	9908	10212	10516	10819	12034	12338	12642
	10033	10344	10656	10967	11278	12522	12833	13144
	10471	10790	11108	11427	11745	13020	13338	13656
	10919	11244	11570	11896	12222	13526	13852	14178
	11375	11708	12042	12375	12708	14042	14375	14708
	11841	12181	12522	12863	13204	14567	14907	15248
	12316	12664	13012	13360	13708	15101	15449	15797
	12800	13156	13511	13867	14222	15644	16000	16356
	13294	13656	14019	14382	14745	16197	16560	16923
	13796	14167	14537	14907	15278	16759	17130	17500
	14308	14686	15064	15442	15819	17331	17708	18086
	14830	15215	15600	15985	16370	17911	18296	18681
	15360	15753	16145	16538	16931	18501	18894	19286
	15900	16300	16700	17100	17500	19100	19500	19900
	16449	16856	17264	17671	18079	19708	20116	20523
	17007	17422	17837	18252	18667	20326	20741	21156
	17575	17997	18419	18442	19264	20953	21375	21797
	18152	18581	19011	19441	19870	21589	22019	22448
	18738	19175	19612	20049	20486	22234	22671	23108
	19333	19778	20222	20667	21111	22889	23333	23778

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	50	57	65	72	80	109	117	124
2	111	126	141	156	170	230	244	259
3	183	206	228	250	272	361	383	406
4	267	296	326	356	385	504	533	563
5	361	398	435	472	509	657	694	731
6	467	511	556	600	644	822	867	911
7	583	635	687	739	791	998	1050	1102
8	711	770	830	889	948	1185	1244	1304
9	850	917	983	1050	1116	1383	1450	1517
10	1000	1074	1148	1222	1296	1593	1667	1741
11	1161	1243	1324	1406	1487	1813	1894	1976
12	1333	1422	1511	1600	1689	2044	2133	2222
13	1517	1613	1709	1806	1902	2287	2383	2480
14	1711	1815	1919	2022	2126	2541	2644	2748
15	1917	2028	2139	2250	2361	2806	2917	3028
16	2133	2252	2370	2489	2607	3081	3200	3319
17	2361	2487	2613	2739	2865	3369	3494	3620
18	2600	2733	2867	3000	3133	3667	3800	3933
19	2850	2991	3131	3272	3413	3976	4117	4257
20	3111	3259	3407	3556	3704	4296	4444	4592
21	3383	3539	3694	3850	4005	4628	4783	4939
22	3667	3830	3993	4156	4318	4970	5133	5296
23	3961	4131	4302	4472	4642	5324	5494	5665
24	4267	4444	4622	4800	4978	5689	5867	6044
25	4583	4769	4954	5139	5324	6065	6250	6435
26	4911	5104	5296	5489	5681	6452	6644	6837
27	5250	5450	5650	5850	6050	6850	7050	7250
28	5600	5807	6015	6222	6430	7259	7467	7674
29	5961	6176	6391	6606	6820	7680	7894	8109
30	6333	6556	6778	7000	7222	8111	8333	8555
31	6717	6946	7176	7406	7635	8554	8783	9013
32	7111	7348	7585	7822	8059	9007	9244	9482
33	7517	7761	8006	8250	8494	9472	9717	9962
34	7933	8185	8437	8689	8941	9948	10200	10452
35	8361	8620	8880	9139	9398	10435	10694	10954
36	8800	9067	9333	9600	9867	10933	11200	11467
37	9250	9524	9798	10072	10346	11443	11717	11991
38	9711	9993	10274	10556	10837	11963	12244	12526
39	10183	10472	10761	11050	11339	12494	12783	13072
40	10667	10963	11259	11556	11852	13037	13333	13630
41	11161	11465	11769	12072	12376	13591	13894	14198
42	11667	11978	12289	12600	12911	14156	14467	14778
43	12183	12502	12820	13139	13457	14731	15050	15369
44	12711	13037	13363	13689	14015	15319	15644	15970
45	13250	13583	13917	14250	14583	15917	16250	16583
46	13800	14141	14481	14822	15163	16526	16867	17207
47	14361	14709	15057	15406	15754	17146	17494	17843
48	14933	15289	15644	16000	16356	17778	18133	18489
49	15517	15880	16243	16606	16968	18420	18783	19146
50	16111	16481	16852	17222	17592	19074	19444	19815
51	16717	17094	17472	17850	18228	19739	20117	20494
52	17333	17719	18104	18489	18874	20415	20800	21185
53	17961	18354	18746	19139	19531	21102	21494	21887
54	18600	19000	19400	19800	20200	21800	22200	22600
55	19250	19657	20065	20472	20880	22509	22917	23324
56	19911	20326	20741	21156	21570	23230	23644	24059
57	20583	21006	21428	21850	22272	23961	24383	24805
58	21267	21696	22126	22556	22985	24704	25133	25563
59	21961	22398	22835	23272	23709	25457	25894	26332
[illegible]	22667	23111	23556	24000	24444	26222	26667	27111

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	52	59	67	74	81	111	119	126
2	119	133	148	163	178	237	252	267
3	200	222	244	267	289	378	400	422
4	296	326	356	385	415	533	563	593
5	407	444	481	519	556	704	741	778
6	533	578	622	667	711	889	933	978
7	674	726	778	830	881	1089	1141	1193
8	830	889	948	1007	1067	1304	1363	1422
9	1000	1067	1133	1200	1267	1533	1600	1667
10	1185	1259	1333	1407	1481	1778	1852	1926
11	1385	1467	1548	1630	1711	2037	2119	2200
12	1600	1689	1778	1867	1956	2311	2400	2489
13	1830	1926	2022	2119	2215	2600	2696	2793
14	2074	2178	2281	2385	2489	2904	3007	3111
15	2333	2444	2556	2667	2778	3222	3333	3444
16	2607	2726	2844	2963	3081	3556	3674	3793
17	2896	3022	3148	3274	3400	3904	4030	4156
18	3200	3333	3467	3600	3733	4267	4400	4533
19	3519	3659	3800	3941	4081	4644	4785	4926
20	3852	4000	4148	4296	4444	5037	5185	5333
21	4200	4356	4511	4067	4822	5444	5600	5756
22	4563	4730	4889	5052	5215	5867	6030	6193
23	4941	5111	5281	5452	5622	6304	6474	6644
24	5333	5511	5689	5867	6044	6756	6933	7111
25	5741	5926	6111	6296	6481	7222	7407	7593
26	6163	6356	6548	6741	6933	7704	7896	8089
27	6600	6800	7000	7200	7400	8200	8400	8600
28	7052	7259	7467	7674	7881	8711	8919	9126
29	7519	7733	7948	8163	8378	9237	9452	9667
30	8000	8222	8444	8667	8889	9778	10000	10222
31	8496	8726	8956	9185	9415	10333	10563	10793
32	9007	9244	9481	9719	9956	10904	11141	11378
33	9533	9778	10022	10267	10511	11489	11733	11978
34	10074	10326	10578	10830	11081	12089	12341	12593
35	10630	10889	11148	11407	11667	12704	12963	13222
36	11200	11467	11733	12000	12267	13333	13600	13867
37	11785	12059	12333	12607	12881	13978	14252	14526
38	12385	12667	12948	13230	13511	14637	14919	15200
39	13000	13289	13578	13867	14156	15311	15600	15889
40	13630	13926	14222	14519	14815	16000	16296	16593
41	14274	14578	14881	15185	15489	16704	17007	17311
42	14933	15244	15556	15867	16178	17422	17733	18044
43	15607	15926	16224	16563	16881	18156	18474	18793
44	16296	16622	16948	17274	17600	18904	19230	19556
45	17000	17333	17667	18000	18333	19667	20000	20333
46	17719	18059	18400	18741	19081	20444	20785	21126
47	18452	18800	19148	19496	19844	21237	21585	21933
48	19200	19556	19911	20267	20622	22044	22400	22756
49	19963	20326	20689	21052	21415	22867	23230	23593
50	20741	20711	21481	21852	22222	23704	24074	24444
51	21533	21911	22289	22667	23044	24556	24933	25311
52	22341	22726	23111	23496	23881	25422	25807	26193
53	23163	23556	23948	24341	24733	26304	26696	27089
54	24000	24400	24800	25200	25600	27200	27600	28000
55	24852	25259	25667	26074	26481	28111	28519	28926
56	25719	26133	26548	26963	27378	29037	29452	29867
57	26600	27022	27444	27867	28289	29978	30400	30822
58	27496	27926	28356	28785	29215	30933	31363	31793
59	28407	28844	29281	29719	30156	31904	32841	32778
60	29333	29778	30222	30667	31111	32889	33333	33778

Depth d	Base 12	Base 14	Base 16	Base 18	Base 20	Base 28	Base 30	Base 32
1	56	63	70	78	85	115	122	130
2	133	148	163	178	193	252	267	281
3	233	256	278	300	322	411	433	456
4	356	385	415	444	474	593	622	652
5	500	537	574	611	648	796	833	870
6	667	711	756	800	844	1022	1067	1111
7	856	907	959	1011	1063	1270	1322	1374
8	1067	1126	1185	1244	1304	1541	1600	1659
9	1300	1367	1433	1500	1567	1833	1900	1967
10	1556	1630	1704	1778	1852	2148	2222	2296
11	1833	1915	1996	2078	2159	2485	2567	2648
12	2133	2222	2311	2400	2489	2844	2933	3022
13	2456	2552	2648	2744	2841	3226	3322	3419
14	2800	2904	3007	3111	3215	3630	3733	3837
15	3167	3278	3389	3500	3611	4056	4167	4278
16	3556	3674	3793	3911	4030	4504	4622	4741
17	3967	4093	4219	4344	4470	4974	5100	5226
18	4400	4533	4667	4800	4933	5467	5600	5733
19	4856	4996	5137	5278	5419	5981	6122	6263
20	5333	5481	5630	5778	5926	6519	6667	6815
21	5833	5989	6144	6300	6456	7078	7233	7389
22	6356	6519	6681	6844	7007	7659	7822	7985
23	6900	7070	7241	7411	7581	8263	8433	8504
24	7467	7644	7822	8000	8178	8889	9067	9144
25	8056	8241	8426	8611	8796	9537	9722	9807
26	8667	8859	9052	9244	9437	10207	10400	10593
27	9300	9500	9700	9900	10100	10900	11100	11300
28	9956	10163	10370	10578	10785	11615	11822	12030
29	10633	10848	11063	11278	11493	12352	12567	12781
30	11333	11556	11778	12000	12222	13111	13333	13556
31	12056	12285	12515	12744	12974	13893	14122	14352
32	12800	13037	13274	13511	13748	14696	14933	15170
33	13567	13811	14056	14300	14544	15522	15767	16011
34	14356	14607	14859	15111	15363	16370	16622	16874
35	15167	15426	15685	15944	16204	17241	17500	17759
36	16000	16267	16533	16800	17067	18133	18400	18667
37	16856	17130	17404	17678	17952	19048	19322	19596
38	17733	18015	18296	18578	18859	19985	20267	20548
39	18633	18922	19211	19500	19789	20944	21233	21522
40	19556	19852	20148	20444	20741	21926	22222	22516
41	20500	20804	21107	21411	21715	22930	23233	23537
42	21467	21778	22089	22400	22711	23956	24267	24578
43	22456	22774	23093	23411	23730	25004	25322	25641
44	23467	23793	24119	24444	24770	26074	26400	26726
45	24500	24833	25167	25500	25833	27167	27500	27833
46	25556	25896	26237	26578	26919	28281	28622	28963
47	26633	26981	27330	27678	28026	29419	29767	30115
48	27733	28089	28444	28800	29156	30578	30933	31289
49	28856	29219	29581	29944	30307	31759	32122	32485
50	30000	30370	30741	31111	31481	32963	33333	33704
51	31167	31544	31922	32300	32678	34189	34567	34944
52	32356	32741	33126	33511	33896	35437	35822	36207
53	33567	33959	34352	34744	35137	36707	37100	37493
54	34800	35200	35600	36000	36400	38000	38400	38800
55	36056	36463	36870	37278	37685	39315	39722	40130
56	37333	37748	38163	38578	38993	40652	41067	41481
57	38633	39056	39478	39900	40322	42011	42433	42856
58	39956	40385	40815	41244	41674	43393	43822	44252
59	41300	41737	42174	42611	43048	44796	45233	45670
60	42667	43111	43556	44000	44444	46222	46667	47111

Hgt.	WIDTH. 1	2	3	4	5	6	7	8	9
0.1	.093	.185	.278	.370	.463	.566	.648	.741	.833
.2	.185	.370	.556	.741	.926	1.111	1.296	1.481	1.667
.3	.278	.556	.833	1.111	1.389	1.667	1.944	2.222	2.500
.4	.370	.741	1.111	1.481	1.852	2.222	2.593	2.963	3.333
.5	.463	.926	1.389	1.852	2.315	2.778	3.241	3.704	4.167
.6	.555	1.111	1.667	2.222	2.778	3.333	3.889	4.444	5.000
.7	.648	1.296	1.944	2.593	3.241	3.889	4.537	5.185	5.833
.8	.741	1.481	2.222	2.963	3.704	4.444	5.185	5.926	6.667
.9	.833	1.667	2.500	3.333	4.167	5.000	4.833	6.667	7.500
1.0	.926	1.852	2.778	3.704	4.630	5.556	6.481	7.407	8.333
.1	1.019	2.037	3.056	4.074	5.093	6.111	7.130	8.148	9.167
.2	1.111	2.222	3.333	4.444	5.556	6.667	7.778	8.889	10.000
.3	1.204	2.407	3.611	4.815	6.019	7.222	8.426	9.630	10.833
.4	1.296	2.593	3.889	5.185	6.481	7.778	9.074	10.370	11.667
.5	1.389	2.778	4.167	5.556	6.944	8.333	9.722	11.111	12.500
.6	1.481	2.963	4.444	5.926	7.407	8.889	10.370	11.852	13.333
.7	1.574	3.148	4.722	6.296	7.870	9.444	11.019	12.593	14.167
.8	1.667	3.333	5.000	6.667	8.333	10.000	11.667	13.333	15.000
.9	1.759	3.519	5.278	7.037	8.796	10.556	12.315	14.074	15.833
2.0	1.852	3.704	5.556	7.407	9.259	11.111	12.963	14.815	16.667
.1	1.944	3.889	5.833	7.778	9.722	11.667	13.611	15.556	17.500
.2	2.037	4.074	6.111	8.148	10.185	12.222	14.259	16.296	18.333
.3	2.130	4.259	6.389	8.519	10.648	12.778	14.907	17.037	19.167
.4	2.222	4.444	6.667	8.889	11.111	13.333	15.556	17.778	20.000
.5	2.315	4.630	6.944	9.259	11.574	13.889	16.204	18.519	20.833
.6	2.407	4.815	7.222	9.630	12.037	14.444	16.852	19.259	21.667
.7	2.500	5.000	7.500	10.000	12.500	15.000	17.500	20.000	22.500
.8	2.593	5.185	7.778	10.370	12.963	15.556	18.148	20.741	23.333
.9	2.685	5.370	8.056	10.741	13.426	16.111	18.796	21.481	24.167
3.0	2.778	5.556	8.333	11.111	13.889	16.667	19.444	22.222	25.000
.1	2.870	5.741	8.611	11.481	14.352	17.222	20.093	22.963	25.833
.2	2.963	5.926	8.889	11.852	14.815	17.778	20.741	23.704	26.667
.3	3.056	6.111	9.167	12.222	15.278	18.333	21.389	24.444	27.500
.4	3.148	6.296	9.444	12.593	15.741	18.889	22.037	25.185	28.333
.5	3.241	6.481	9.722	12.963	16.204	19.444	22.685	25.926	29.167
.6	3.333	6.667	10.000	13.333	16.667	20.000	23.333	26.667	30.000
.7	3.426	6.852	10.278	13.704	17.130	20.556	23.981	27.407	30.833
.8	3.519	7.037	10.556	14.074	17.593	21.111	24.630	28.148	31.667
.9	3.611	7.222	10.833	14.444	18.056	21.667	25.278	28.889	32.500
4.0	3.704	7.407	11.111	14.815	18.519	22.222	25.926	29.630	33.333
.1	3.796	7.593	11.389	15.185	18.981	22.778	26.574	30.370	34.167
.2	3.889	7.778	11.667	15.556	19.444	23.333	27.222	31.111	35.000
.3	3.981	7.963	11.944	15.926	19.907	23.889	27.870	31.852	35.833
.4	4.074	8.148	12.222	16.296	20.370	24.444	28.519	32.593	36.667
.5	4.167	8.333	12.500	16.667	20.833	25.000	29.167	33.333	37.500
.6	4.259	8.519	12.778	17.037	21.296	25.556	29.815	34.074	38.333
.7	4.352	8.704	13.056	17.407	21.759	26.111	30.463	34.815	39.167
.8	4.444	8.889	13.333	17.778	22.222	26.667	31.111	35.556	40.000
.9	4.537	9.074	13.611	18.148	22.685	27.222	31.759	36.296	40.833
5.0	4.630	9.259	13.889	18.519	23.148	27.778	32.407	37.037	41.667
.1	4.722	9.444	14.167	18.889	23.611	28.333	33.056	37.778	42.500
.2	4.815	9.630	14.444	19.259	24.074	28.889	33.704	38.519	43.333
.3	4.907	9.815	14.722	19.630	24.537	29.444	34.352	39.259	44.167
.4	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000
.5	5.093	10.185	15.278	20.370	25.463	30.556	35.648	40.741	45.833
.6	5.185	10.370	15.556	20.741	25.926	31.111	36.296	41.481	46.667
.7	5.278	10.556	15.833	21.111	26.389	31.667	36.944	42.222	47.500
.8	5.370	10.741	16.111	21.481	26.852	32.222	37.593	42.963	48.333
.9	5.463	10.926	16.389	21.852	27.315	32.778	38.241	43.704	49.1
.0	5.556	11.111	16.667	22.222	27.778	33.333	38.889	44.444	[illegible]

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
6.1	5.648	11.296	16.944	22.593	28.241	33.889	39.537	45.185	50.833
.2	5.741	11.481	17.222	22.963	28.704	34.444	40.185	45.926	51.667
.3	5.833	11.667	17.500	23.333	29.167	35.000	40.833	46.667	52.500
.4	5.926	11.852	17.778	23.704	29.630	35.556	41.481	47.407	53.333
.5	6.019	12.037	18.056	24.074	30.093	36.111	42.130	48.148	54.167
.6	6.111	12.222	18.333	24.444	30.556	36.667	42.778	48.889	55.000
.7	6.204	12.407	18.611	24.815	31.019	37.222	43.426	49.630	55.833
.8	6.296	12.593	18.889	25.185	31.481	37.778	44.074	50.370	56.667
.9	6.389	12.778	19.167	25.556	31.944	38.333	44.722	51.111	57.500
7.0	6.481	12.963	19.444	25.926	32.407	38.889	45.370	51.852	58.333
.1	6.574	13.148	19.722	26.296	32.870	39.444	46.019	52.593	59.167
.2	6.667	13.333	20.000	26.667	33.333	40.000	46.667	53.333	60.000
.3	6.759	13.519	20.278	27.037	33.796	40.556	47.315	54.074	60.833
.4	6.852	13.704	20.556	27.407	34.259	41.111	47.963	54.815	61.667
.5	6.944	13.889	20.833	27.778	34.722	41.667	48.611	55.556	62.500
.6	7.037	14.074	21.111	28.148	35.185	42.222	49.259	56.296	63.333
.7	7.130	14.259	21.389	28.519	35.648	42.778	49.907	57.037	64.167
.8	7.222	14.444	21.667	28.889	36.111	43.333	50.556	57.778	65.000
.9	7.315	14.630	21.944	29.259	36.574	43.889	51.204	58.519	65.833
8.0	7.407	14.815	22.222	29.630	37.037	44.444	51.852	59.259	66.667
.1	7.500	15.000	22.500	30.000	37.500	45.000	52.500	60.000	67.500
.2	7.593	15.185	22.778	30.370	37.963	45.556	53.148	60.741	68.333
.3	7.685	15.370	23.056	30.741	38.426	46.111	53.796	61.481	69.167
.4	7.778	15.556	23.333	31.111	38.889	46.667	54.444	62.222	70.000
.5	7.870	15.741	23.611	31.481	39.352	47.222	55.093	62.963	70.833
.6	7.963	15.926	23.889	31.852	39.815	47.778	55.741	63.704	71.667
.7	8.056	16.111	24.167	32.222	40.278	48.333	56.389	64.444	72.500
.8	8.148	16.296	24.444	32.593	40.741	48.889	57.037	65.185	73.333
.9	8.241	16.481	24.722	32.963	41.204	49.444	57.685	65.926	74.167
9.0	8.333	16.667	25.000	33.333	41.667	50.000	58.333	66.667	75.000
.1	8.426	16.852	25.278	33.704	42.130	50.556	58.981	67.407	75.833
.2	8.519	17.037	25.556	34.074	42.593	51.111	59.630	68.148	76.667
.3	8.611	17.222	25.833	34.444	43.056	51.667	60.278	68.889	77.500
.4	8.704	17.407	26.111	34.815	43.519	52.222	60.926	69.630	78.333
.5	8.796	17.593	26.389	35.185	43.981	52.778	61.574	70.370	79.167
.6	8.889	17.778	26.667	35.556	44.444	53.333	62.222	71.111	80.000
.7	8.981	17.963	26.944	35.926	44.907	53.889	62.870	71.852	80.833
.8	9.074	18.148	27.222	36.296	45.370	54.444	63.519	72.593	81.667
.9	9.167	18.333	27.500	36.667	45.833	55.000	64.167	73.333	82.500
10.0	9.259	18.519	27.778	37.037	46.296	55.556	64.815	74.074	83.333
.1	9.352	18.704	28.056	37.407	46.759	56.111	65.463	74.815	84.167
.2	9.444	18.889	28.333	37.778	47.222	56.667	66.111	75.556	85.000
.3	9.537	19.074	28.611	38.148	47.685	57.222	66.759	76.296	85.833
.4	9.630	19.259	28.889	38.519	48.148	57.778	67.407	77.037	86.667
.5	9.722	19.444	29.167	38.889	48.611	58.333	68.056	77.778	87.500
.6	9.815	19.630	29.444	39.259	49.074	58.889	68.704	78.519	88.333
.7	9.907	19.815	29.722	39.630	49.537	59.444	69.352	79.259	89.167
.8	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000
.9	10.093	20.185	30.278	40.370	50.463	60.556	70.648	80.741	90.833
11.0	10.185	20.370	30.556	40.741	50.926	61.111	71.296	81.481	91.667
.1	10.278	20.556	30.833	41.111	51.389	61.667	71.944	82.222	92.500
.2	10.370	20.741	31.111	41.481	51.852	62.222	72.593	82.963	93.333
.3	10.463	20.926	31.389	41.852	52.315	62.778	73.241	83.704	94.167
.4	10.556	21.111	31.667	42.222	52.778	63.333	73.889	84.444	95.000
.5	10.648	21.296	31.944	42.593	53.241	63.889	74.537	85.185	95.833
.6	10.741	21.481	32.222	42.963	53.704	64.444	75.185	85.926	96.667
.7	10.833	21.667	32.500	43.333	54.167	65.000	75.833	86.667	97.500
.8	10.926	21.852	32.778	43.704	54.630	65.556	76.481	87.407	98.333
.9	*11.019*	*22.037*	*33.056*	44.074	55.093	66.111	77.130	88.148	99.167
2.0	*11.111*	*22.222*	*33.333*	44.444	55.556	66.667	77.778	88.889	100.000

	WIDTH.								
	1	2	3	4	5	6	7	8	9
2.1	11.204	22.407	33.611	44.815	56.019	67.222	78.426	89.630	100.833
.2	11.296	22.593	33.889	45.185	56.481	67.778	79.074	90.370	101.667
.3	11.389	22.778	34.167	45.556	56.944	68.333	79.722	91.111	102.500
.4	11.481	22.963	34.444	45.926	57.407	68.889	80.370	91.852	103.333
.5	11.574	23.148	34.722	46.296	57.870	69.444	81.019	92.593	104.167
.6	11.667	23.333	35.000	46.667	58.333	70.000	81.667	93.333	105.000
.7	11.759	23.519	35.278	47.037	58.796	70.556	82.315	94.074	105.833
.8	11.852	23.704	35.556	47.407	59.259	71.111	82.963	94.815	106.667
.9	11.944	23.889	35.833	47.778	59.722	71.667	83.611	95.556	107.500
3.0	12.037	24.074	36.111	48.148	60.185	72.222	84.259	96.296	108.333
.1	12.130	24.259	36.389	48.519	60.648	72.778	84.907	97.037	109.167
.2	12.222	24.444	36.667	48.889	61.111	73.333	85.556	97.778	110.000
.3	12.315	24.630	36.944	49.259	61.574	73.889	86.204	98.519	110.833
.4	12.407	24.815	37.222	49.630	62.037	74.444	86.852	99.259	111.667
.5	12.500	25.000	37.500	50.000	62.500	75.000	87.500	100.000	112.500
.6	12.593	25.185	37.778	50.370	62.963	75.556	88.148	100.741	113.333
.7	12.685	25.370	38.056	50.741	63.426	76.111	88.796	101.481	114.167
.8	12.778	25.556	38.333	51.111	63.889	76.667	89.444	102.222	115.000
.9	12.870	25.741	38.611	51.481	64.352	77.222	90.093	102.963	115.833
4.0	12.963	25.926	38.889	51.852	64.815	77.778	90.741	103.704	116.667
.1	13.056	26.111	39.167	52.222	65.278	78.333	91.389	104.444	117.500
.2	13.148	26.296	39.444	52.593	65.741	78.889	92.037	105.185	118.333
.3	13.241	26.481	39.722	52.963	66.204	79.444	92.685	105.926	119.167
.4	13.333	26.667	40.000	53.333	66.667	80.000	93.333	106.667	120.000
.5	13.426	26.852	40.278	53.704	67.130	80.556	93.981	107.407	120.833
.6	13.519	27.037	40.556	54.074	67.593	81.111	94.630	108.148	121.667
.7	13.611	27.222	40.833	54.444	68.056	81.667	95.278	108.889	122.500
.8	13.704	27.407	41.111	54.815	68.519	82.222	95.926	109.630	123.333
.9	13.796	27.593	41.389	55.185	68.981	82.778	96.574	110.370	124.167
5.0	13.889	27.778	41.667	55.556	69.444	83.333	97.222	111.111	125.000
.1	13.981	27.963	41.944	55.926	69.907	83.889	97.870	111.852	125.833
.2	14.074	28.148	42.222	56.296	70.370	84.444	98.519	112.593	126.667
.3	14.167	28.333	42.500	56.667	70.833	85.000	99.167	113.333	127.500
.4	14.259	28.519	42.778	57.037	71.296	85.556	99.815	114.074	128.333
.5	14.352	28.704	43.056	57.407	71.759	86.111	100.463	114.815	129.167
.6	14.444	28.889	43.333	57.778	72.222	86.667	101.111	115.556	130.000
.7	14.537	29.074	43.611	58.148	72.685	87.222	101.759	116.296	130.833
.8	14.630	29.259	43.889	58.519	73.148	87.778	102.407	117.037	131.667
.9	14.722	29.444	44.167	58.889	73.611	88.333	103.056	117.778	132.500
6.0	14.815	29.630	44.444	59.259	74.074	88.889	103.704	118.519	133.333
.1	14.907	29.815	44.722	59.630	74.537	89.444	104.352	119.259	134.167
.2	15.000	30.000	45.000	60.000	75.000	90.000	105.000	120.000	135.000
.3	15.093	30.185	45.278	60.370	75.463	90.556	105.648	120.741	135.833
.4	15.185	30.370	45.556	60.741	75.926	91.111	106.296	121.481	136.667
.5	15.278	30.556	45.833	61.111	76.389	91.667	106.944	122.222	137.500
.6	15.370	30.741	46.111	61.481	76.852	92.222	107.593	122.963	138.333
.7	15.463	30.926	46.389	61.852	77.315	92.778	108.241	123.704	139.167
.8	15.556	31.111	46.667	62.222	77.778	93.333	108.889	124.444	140.000
.9	15.648	31.296	46.944	62.593	78.241	93.889	109.537	125.185	140.833
7.0	15.741	31.481	47.222	62.963	78.704	94.444	110.185	125.926	141.667
.1	15.833	31.667	47.500	63.333	79.167	95.000	110.833	126.667	142.500
.2	15.926	31.852	47.778	63.704	79.630	95.556	111.481	127.407	143.333
.3	16.019	32.037	48.056	64.074	80.093	96.111	112.130	128.148	144.167
.4	16.111	32.222	48.333	64.444	80.556	96.667	112.778	128.889	145.000
.5	16.204	32.407	48.611	64.815	81.019	97.222	113.426	129.630	145.833
.6	16.296	32.593	48.889	65.185	81.481	97.778	114.074	130.370	146.667
.7	16.389	32.778	49.167	65.556	81.944	98.333	114.722	131.111	147.500
.8	16.481	32.963	49.444	65.926	82.407	98.889	115.370	131.852	148.333
.9	16.574	33.148	49.722	66.296	82.870	99.444	116.019	132.593	149.167
8.0	16.667	33.333	50.000	66.667	83.333	100.000	116.667	133.333	150.000

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
6.1	5.648	11.296	16.944	22.593	28.241	33.889	39.537	45.185	50.833
.2	5.741	11.481	17.222	22.963	28.704	34.444	40.185	45.926	51.667
.3	5.833	11.667	17.500	23.333	29.167	35.000	40.833	46.667	52.500
.4	5.926	11.852	17.778	23.704	29.630	35.556	41.481	47.407	53.333
.5	6.019	12.037	18.056	24.074	30.093	36.111	42.130	48.148	54.167
.6	6.111	12.222	18.333	24.444	30.556	36.667	42.778	48.889	55.000
.7	6.204	12.407	18.611	24.815	31.019	37.222	43.426	49.630	55.833
.8	6.296	12.593	18.889	25.185	31.481	37.778	44.074	50.370	56.667
.9	6.389	12.778	19.167	25.556	31.944	38.333	44.722	51.111	57.500
7.0	6.481	12.963	19.444	25.926	32.407	38.889	45.370	51.852	58.333
.1	6.574	13.148	19.722	26.296	32.870	39.444	46.019	52.593	59.167
.2	6.667	13.333	20.000	26.667	33.333	40.000	46.667	53.333	60.000
.3	6.759	13.519	20.278	27.037	33.796	40.556	47.315	54.074	60.833
.4	6.852	13.704	20.556	27.407	34.259	41.111	47.963	54.815	61.667
.5	6.944	13.889	20.833	27.778	34.722	41.667	48.611	55.556	62.500
.6	7.037	14.074	21.111	28.148	35.185	42.222	49.259	56.296	63.333
.7	7.130	14.259	21.389	28.519	35.648	42.778	49.907	57.037	64.167
.8	7.222	14.444	21.667	28.889	36.111	43.333	50.556	57.778	65.000
.9	7.315	14.630	21.944	29.259	36.574	43.889	51.204	58.519	65.833
8.0	7.407	14.815	22.222	29.630	37.037	44.444	51.852	59.259	66.667
.1	7.500	15.000	22.500	30.000	37.500	45.000	52.500	60.000	67.500
.2	7.593	15.185	22.778	30.370	37.963	45.556	53.148	60.741	68.333
.3	7.685	15.370	23.056	30.741	38.426	46.111	53.796	61.481	69.167
.4	7.778	15.556	23.333	31.111	38.889	46.667	54.444	62.222	70.000
.5	7.870	15.741	23.611	31.481	39.352	47.222	55.093	62.963	70.833
.6	7.963	15.926	23.889	31.852	39.815	47.778	55.741	63.704	71.667
.7	8.056	16.111	24.167	32.222	40.278	48.333	56.389	64.444	72.500
.8	8.148	16.296	24.444	32.593	40.741	48.889	57.037	65.185	73.333
.9	8.241	16.481	24.722	32.963	41.204	49.444	57.685	65.926	74.167
9.0	8.333	16.667	25.000	33.333	41.667	50.000	58.333	66.667	75.000
.1	8.426	16.852	25.278	33.704	42.130	50.556	58.981	67.407	75.833
.2	8.519	17.037	25.556	34.074	42.593	51.111	59.630	68.148	76.667
.3	8.611	17.222	25.833	34.444	43.056	51.667	60.278	68.889	77.500
.4	8.704	17.407	26.111	34.815	43.519	52.222	60.926	69.630	78.333
.5	8.796	17.593	26.389	35.185	43.981	52.778	61.574	70.370	79.167
.6	8.889	17.778	26.667	35.556	44.444	53.333	62.222	71.111	80.000
.7	8.981	17.963	26.944	35.926	44.907	53.889	62.870	71.852	80.833
.8	9.074	18.148	27.222	36.296	45.370	54.444	63.519	72.593	81.667
.9	9.167	18.333	27.500	36.667	45.833	55.000	64.167	73.333	82.500
10.0	9.259	18.519	27.778	37.037	46.296	55.556	64.815	74.074	83.333
.1	9.352	18.704	28.056	37.407	46.759	56.111	65.463	74.815	84.167
.2	9.444	18.889	28.333	37.778	47.222	56.667	66.111	75.556	85.000
.3	9.537	19.074	28.611	38.148	47.685	57.222	66.759	76.296	85.833
.4	9.630	19.259	28.889	38.519	48.148	57.778	67.407	77.037	86.667
.5	9.722	19.444	29.167	38.889	48.611	58.333	68.056	77.778	87.500
.6	9.815	19.630	29.444	39.259	49.074	58.889	68.704	78.519	88.333
.7	9.907	19.815	29.722	39.630	49.537	59.444	69.352	79.259	89.167
.8	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000
.9	10.093	20.185	30.278	40.370	50.463	60.556	70.648	80.741	90.833
11.0	10.185	20.370	30.556	40.741	50.926	61.111	71.296	81.481	91.667
.1	10.278	20.556	30.833	41.111	51.389	61.667	71.944	82.222	92.500
.2	10.370	20.741	31.111	41.481	51.852	62.222	72.593	82.963	93.333
.3	10.463	20.926	31.389	41.852	52.315	62.778	73.241	83.704	94.167
.4	10.556	21.111	31.667	42.222	52.778	63.333	73.889	84.444	95.000
.5	*10.648*	*21.296*	31.944	42.593	53.241	63.889	74.537	85.185	95.833
[illegible]	*0.741*	*21.481*	32.222	42.963	53.704	64.444	75.185	85.926	96.667
[illegible]	*.833*	*21.667*	32.500	43.333	54.167	65.000	75.833	86.667	97.500
[illegible]	*.926*	*21.852*	32.778	43.704	54.630	65.556	76.481	87.407	98.33
[illegible]	*.019*	*22.037*	33.056	44.074	55.093	66.111	77.130	88.148	99.1
[illegible]	*11*	*22.222*	33.333	44.444	55.556	66.667	77.778	88.889	100.

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
12.1	11.204	22.407	33.611	44.815	56.019	67.222	78.426	89.630	100.833
.2	11.296	22.593	33.889	45.185	56.481	67.778	79.074	90.370	101.667
.3	11.389	22.778	34.167	45.556	56.944	68.333	79.722	91.111	102.500
.4	11.481	22.963	34.444	45.926	57.407	68.889	80.370	91.852	103.333
.5	11.574	23.148	34.722	46.296	57.870	69.444	81.019	92.593	104.167
.6	11.667	23.333	35.000	46.667	58.333	70.000	81.667	93.333	105.000
.7	11.759	23.519	35.278	47.037	58.796	70.556	82.315	94.074	105.833
.8	11.852	23.704	35.556	47.407	59.259	71.111	82.963	94.815	106.667
.9	11.944	23.889	35.833	47.778	59.722	71.667	83.611	95.556	107.500
13.0	12.037	24.074	36.111	48.148	60.185	72.222	84.259	96.296	108.333
.1	12.130	24.259	36.389	48.519	60.648	72.778	84.907	97.037	109.167
.2	12.222	24.444	36.667	48.889	61.111	73.333	85.556	97.778	110.000
.3	12.315	24.630	36.944	49.259	61.574	73.889	86.204	98.519	110.833
.4	12.407	24.815	37.222	49.630	62.037	74.444	86.852	99.259	111.667
.5	12.500	25.000	37.500	50.000	62.500	75.000	87.500	100.000	112.500
.6	12.593	25.185	37.778	50.370	62.963	75.556	88.148	100.741	113.333
.7	12.685	25.370	38.056	50.741	63.426	76.111	88.796	101.481	114.167
.8	12.778	25.556	38.333	51.111	63.889	76.667	89.444	102.222	115.000
.9	12.870	25.741	38.611	51.481	64.352	77.222	90.093	102.963	115.833
14.0	12.963	25.926	38.889	51.852	64.815	77.778	90.741	103.704	116.667
.1	13.056	26.111	39.167	52.222	65.278	78.333	91.389	104.444	117.500
.2	13.148	26.296	39.444	52.593	65.741	78.889	92.037	105.185	118.333
.3	13.241	26.481	39.722	52.963	66.204	79.444	92.685	105.926	119.167
.4	13.333	26.667	40.000	53.333	66.667	80.000	93.333	106.667	120.000
.5	13.426	26.852	40.278	53.704	67.130	80.556	93.981	107.407	120.833
.6	13.519	27.037	40.556	54.074	67.593	81.111	94.630	108.148	121.667
.7	13.611	27.222	40.833	54.444	68.056	81.667	95.278	108.889	122.500
.8	13.704	27.407	41.111	54.815	68.519	82.222	95.926	109.630	123.333
.9	13.796	27.593	41.389	55.185	68.981	82.778	96.574	110.370	124.167
15.0	13.889	27.778	41.667	55.556	69.444	83.333	97.222	111.111	125.000
.1	13.981	27.963	41.944	55.926	69.907	83.889	97.870	111.852	125.833
.2	14.074	28.148	42.222	56.296	70.370	84.444	98.519	112.593	126.667
.3	14.167	28.333	42.500	56.667	70.833	85.000	99.167	113.333	127.500
.4	14.259	28.519	42.778	57.037	71.296	85.556	99.815	114.074	128.333
.5	14.352	28.704	43.056	57.407	71.759	86.111	100.463	114.815	129.167
.6	14.444	28.889	43.333	57.778	72.222	86.667	101.111	115.556	130.000
.7	14.537	29.074	43.611	58.148	72.685	87.222	101.759	116.296	130.833
.8	14.630	29.259	43.889	58.519	73.148	87.778	102.407	117.037	131.667
.9	14.722	29.444	44.167	58.889	73.611	88.333	103.056	117.778	132.500
16.0	14.815	29.630	44.444	59.259	74.074	88.889	103.704	118.519	133.333
.1	14.907	29.815	44.722	59.630	74.537	89.444	104.352	119.259	134.167
.2	15.000	30.000	45.000	60.000	75.000	90.000	105.000	120.000	135.000
.3	15.093	30.185	45.278	60.370	75.463	90.556	105.648	120.741	135.833
.4	15.185	30.370	45.556	60.741	75.926	91.111	106.296	121.481	136.667
.5	15.278	30.556	45.833	61.111	76.389	91.667	106.944	122.222	137.500
.6	15.370	30.741	46.111	61.481	76.852	92.222	107.593	122.963	138.333
.7	15.463	30.926	46.389	61.852	77.315	92.778	108.241	123.704	139.167
.8	15.556	31.111	46.667	62.222	77.778	93.333	108.889	124.444	140.000
.9	15.648	31.296	46.944	62.593	78.241	93.889	109.537	125.185	140.833
17.0	15.741	31.481	47.222	62.963	78.704	94.444	110.185	125.926	141.667
.1	15.833	31.667	47.500	63.333	79.167	95.000	110.833	126.667	142.500
.2	15.926	31.852	47.778	63.704	79.630	95.556	111.481	127.407	143.335
.3	16.019	32.037	48.056	64.074	80.093	96.111	112.130	128.148	144.167
.4	16.111	32.222	48.333	64.444	80.556	96.667	112.778	128.889	145.000
.5	16.204	32.407	48.611	64.815	81.019	97.222	113.426	129.630	145.833
.6	16.296	32.593	48.889	65.185	81.481	97.778	114.074	130.370	146.667
.7	16.389	32.778	49.167	65.556	81.944	98.333	114.722	131.111	147.500
.8	16.481	32.963	49.444	65.926	82.407	98.889	115.370	131.852	148.33
.9	16.574	33.148	49.722	66.296	82.870	99.444	116.019	132.593	149.
8.0	16.667	33.333	50.000	66.667	83.333	100.000	116.667	133.333	150

Hgt.	WIDTH. 1	2	3	4	5	6	7	8	9
18.1	16.759	33.519	50.278	67.037	83.796	100.556	117.315	134.074	150.833
.2	16.852	33.704	50.556	67.407	84.259	101.111	117.963	134.815	151.667
.3	16.944	33.889	50.833	67.778	84.722	101.667	118.611	135.556	152.500
.4	17.037	34.074	51.111	68.148	85.185	102.222	119.259	136.296	153.333
.5	17.130	34.259	51.389	68.519	85.648	102.778	119.907	137.037	154.167
.6	17.222	34.444	51.667	68.889	86.111	103.333	120.556	137.778	155.000
.7	17.315	34.630	51.944	69.259	86.574	103.889	121.204	138.519	155.833
.8	17.407	34.815	52.222	69.630	87.037	104.444	121.852	139.259	156.667
.9	17.500	35.000	52.500	70.000	87.500	105.000	122.500	140.000	157.500
19.0	17.593	35.185	52.778	70.370	87.963	105.556	123.148	140.741	158.333
.1	17.685	35.370	53.056	70.741	88.426	106.111	123.796	141.481	159.167
.2	17.778	35.556	53.333	71.111	88.889	106.667	124.444	142.222	160.000
.3	17.870	35.741	53.611	71.481	89.352	107.222	125.093	142.963	160.833
.4	17.963	35.926	53.889	71.852	89.815	107.778	125.741	143.704	161.667
.5	18.056	36.111	54.167	72.222	90.278	108.333	126.389	144.444	162.500
.6	18.148	36.296	54.444	72.593	90.741	108.889	127.037	145.185	163.333
.7	18.241	36.481	54.722	72.963	91.204	109.444	127.685	145.926	164.167
.8	18.333	36.667	55.000	73.333	91.667	110.000	128.333	146.667	165.000
.9	18.426	36.852	55.278	73.704	92.130	110.556	128.981	147.407	165.833
20.0	18.519	37.037	55.556	74.074	92.593	111.111	129.630	148.148	166.667
.1	18.611	37.222	55.833	74.444	93.056	111.667	130.278	148.889	167.500
.2	18.704	37.407	56.111	74.815	93.519	112.222	130.926	149.630	168.333
.3	18.796	37.593	56.389	75.185	93.981	112.778	131.574	150.370	169.167
.4	18.889	37.778	56.667	75.556	94.444	113.333	132.222	151.111	170.000
.5	18.981	37.963	56.944	75.926	94.907	113.889	132.870	151.852	170.833
.6	19.074	38.148	57.222	76.296	95.370	114.444	133.519	152.593	171.667
.7	19.167	38.333	57.500	76.667	95.833	115.000	134.167	153.333	172.500
.8	19.259	38.519	57.778	77.037	96.296	115.556	134.815	154.074	173.333
.9	19.352	38.704	58.056	77.407	96.759	116.111	135.463	154.815	174.167
21.0	19.444	38.889	58.333	77.778	97.222	116.667	136.111	155.556	175.000
.1	19.537	39.074	58.611	78.148	97.685	117.222	136.759	156.296	175.833
.2	19.630	39.259	58.889	78.519	98.148	117.778	137.407	157.037	176.667
.3	19.722	39.444	59.167	78.889	98.611	118.333	138.056	157.778	177.500
.4	19.815	39.630	59.444	79.259	99.074	118.889	138.704	158.519	178.333
.5	19.907	39.815	59.722	79.630	99.537	119.444	139.352	159.259	179.167
.6	20.000	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000
.7	20.093	40.185	60.278	80.370	100.463	120.556	140.648	160.741	180.833
.8	20.185	40.370	60.556	80.741	100.926	121.111	141.296	161.481	181.667
.9	20.278	40.556	60.833	81.111	101.389	121.667	141.944	162.222	182.500
22.0	20.370	40.741	61.111	81.481	101.852	122.222	142.593	162.963	183.333
.1	20.463	40.926	61.389	81.852	102.315	122.778	143.241	163.704	184.167
.2	20.556	41.111	61.667	82.222	102.778	123.333	143.889	164.444	185.000
.3	20.648	41.296	61.944	82.593	103.241	123.889	144.537	165.185	185.833
.4	20.741	41.481	62.222	82.963	103.704	124.444	145.185	165.926	186.667
.5	20.833	41.667	62.500	83.333	104.167	125.000	145.833	166.667	187.500
.6	20.926	41.852	62.778	83.704	104.630	125.556	146.481	167.407	188.333
.7	21.019	42.037	63.056	84.074	105.093	126.111	147.130	168.148	189.167
.8	21.111	42.222	63.333	84.444	105.556	126.667	147.778	168.889	190.000
.9	21.204	42.407	63.611	84.815	106.019	127.222	148.426	169.630	190.833
23.0	21.296	42.593	63.889	85.185	106.481	127.778	149.074	170.370	191.667
.1	21.389	42.778	64.167	85.556	106.944	128.333	149.722	171.111	192.500
.2	21.481	42.963	64.444	85.926	107.407	128.889	150.370	171.852	193.333
.3	21.574	43.148	64.722	86.296	107.870	129.444	151.019	172.593	194.167
.4	21.667	43.333	65.000	86.667	108.333	130.000	151.667	173.333	195.000
.5	21.759	43.519	65.278	87.037	108.796	130.556	152.315	174.074	195.833
.6	21.852	43.704	65.556	87.407	109.259	131.111	152.963	174.815	196.667
[illegible]	.944	43.889	65.833	87.778	109.722	131.667	153.611	175.556	197.500
[illegible]	.037	44.074	66.111	88.148	110.185	132.222	154.259	176.296	198.33
[illegible]	.130	44.259	66.389	88.519	110.648	132.778	154.907	177.037	199.1
[illegible]	22	44.444	66.667	88.889	111.111	133.333	155.556	177.778	200.

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
24.1	22.315	44.630	66.944	89.259	111.574	133.889	156.204	178.519	200.833
.2	22.407	44.815	67.222	89.630	112.037	134.444	156.852	179.259	201.667
.3	22.500	45.000	67.500	90.000	112.500	135.000	157.500	180.000	202.500
.4	22.593	45.185	67.778	90.370	112.963	135.556	158.148	180.741	203.333
.5	22.685	45.370	68.056	90.741	113.426	136.111	158.796	181.481	204.167
.6	22.778	45.556	68.333	91.111	113.889	136.667	159.444	182.222	205.000
.7	22.870	45.741	68.611	91.481	114.352	137.222	160.093	182.963	205.833
.8	22.963	45.926	68.889	91.852	114.815	137.778	160.741	183.704	206.667
.9	23.056	46.111	69.167	92.222	115.278	138.333	161.389	184.444	207.500
25.0	23.148	46.296	69.444	92.593	115.741	138.889	162.037	185.185	208.333
.1	23.241	46.481	69.722	92.963	116.204	139.444	162.685	185.926	209.167
.2	23.333	46.667	70.000	93.333	116.667	140.000	163.333	186.667	210.000
.3	23.426	46.852	70.278	93.704	117.130	140.556	163.981	187.407	210.833
.4	23.519	47.037	70.556	94.074	117.593	141.111	164.630	188.148	211.667
.5	23.611	47.222	70.833	94.444	118.056	141.667	165.278	188.889	212.500
.6	23.704	47.407	71.111	94.815	118.519	142.222	165.926	189.630	213.333
.7	23.796	47.593	71.389	95.185	118.981	142.778	166.574	190.370	214.167
.8	23.889	47.778	71.667	95.556	119.444	143.333	167.222	191.111	215.000
.9	23.981	47.963	71.944	95.926	119.907	143.889	167.870	191.852	215.833
26.0	24.074	48.148	72.222	96.296	120.370	144.444	168.519	192.593	216.667
.1	24.167	48.333	72.500	96.667	120.833	145.000	169.167	193.333	217.500
.2	24.259	48.519	72.778	97.0 7	121.296	145.556	169.815	194.074	218.333
.3	24.352	48.704	73.056	97.407	121.759	146.111	170.463	194.815	219.167
.4	24.444	48.889	73.333	97.778	122.222	146.667	171.111	195.556	220.000
.5	24.537	49.074	73.611	98.148	122.685	147.222	171.759	196.296	220.833
.6	24.630	49.259	73.889	98.519	123.148	147.778	172.407	197.037	221.667
.7	24.722	49.444	74.167	98.889	123.611	148.333	173.056	197.778	222.500
.8	24.815	49.630	74.444	99.259	124.074	148.889	173.704	198.519	223.333
.9	24.907	49.815	74.722	99.630	124.537	149.444	174.352	199.259	224.167
27.0	25.000	50.000	75.000	100.000	125.000	150.000	175.000	200.000	225.000
.1	25.093	50.185	75.278	100.370	125.463	150.556	175.648	200.741	225.833
.2	25.185	50.370	75.556	100.741	125.926	151.111	176.296	201.481	226.667
.3	25.278	50.556	75.833	101.111	126.389	151.667	176.944	202.222	227.500
.4	25.370	50.741	76.111	101.481	126.852	152.222	177.593	202.963	228.333
.5	25.463	50.926	76.389	101.852	127.315	152.778	178.241	203.704	229.167
.6	25.556	51.111	76.667	102.222	127.778	153.333	178.889	204.444	230.000
.7	25.648	51.296	76.944	102.593	128.241	153.889	179.537	205.185	230.833
.8	25.741	51.481	77.222	102.963	128.704	154.444	180.185	205.926	231.667
.9	25.833	51.667	77.500	103.333	129.167	155.000	180.833	206.667	232.500
28.0	25.926	51.852	77.778	103.704	129.630	155.556	181.481	207.407	233.333
.1	26.019	52.037	78.056	104.074	130.093	156.111	182.130	208.148	234.167
.2	26.111	52.222	78.333	104.444	130.556	156.667	182.778	208.889	235.000
.3	26.204	52.407	78.611	104.815	131.019	157.222	183.426	209.630	235.833
.4	26.296	52.593	78.889	105.185	131.481	157.778	184.074	210.370	236.667
.5	26.389	52.778	79.167	105.556	131.944	158.333	184.722	211.111	237.500
.6	26.481	52.963	79.444	105.926	132.407	158.889	185.370	211.852	238.333
.7	26.574	53.148	79.722	106.296	132.870	159.444	186.019	212.593	239.167
.8	26.667	53.333	80.000	106.667	133.333	160.000	186.667	213.333	240.000
.9	26.759	53.519	80.278	107.037	133.796	160.556	187.315	214.074	240.833
29.0	26.852	53.704	80.556	107.407	134.259	161.111	187.963	214.815	241.667
.1	26.944	53.889	80.833	107.778	134.722	161.667	188.611	215.556	242.500
.2	27.037	54.074	81.111	108.148	135.185	162.222	189.259	216.296	243.333
.3	27.130	54.259	81.389	108.519	135.648	162.778	189.907	217.037	244.167
.4	27.222	54.444	81.667	108.889	136.111	163.333	190.556	217.778	245.000
.5	27.315	54.630	81.944	109.259	136.574	163.889	191.204	218.519	245.833
.6	27.407	54.815	82.222	109.630	137.037	164.444	191.852	219.259	246.667
.7	27.500	55.000	82.500	110.000	137.500	165.000	192.500	220.000	247.500
.8	27.593	55.185	82.778	110.370	137.963	165.556	193.148	220.741	248.33
.9	27.685	55.370	83.056	110.741	138.426	166.111	193.796	221.481	249.
30.0	27.778	55.556	83.333	111.111	138.889	166.667	194.444	222.222	2

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
30.1	27.870	55.741	83.611	111.481	139.352	167.222	195.093	222.963	250.833
.2	27.963	55.926	83.889	111.852	139.815	167.778	195.741	223.704	251.667
.3	28.056	56.111	84.167	112.222	140.278	168.333	196.389	224.444	252.500
.4	28.148	56.296	84.444	112.593	140.741	168.889	197.037	225.185	253.333
.5	28.241	56.481	84.722	112.963	141.204	169.444	197.685	225.926	254.167
.6	28.333	56.667	85.000	113.333	141.667	170.000	198.333	226.667	255.000
.7	28.426	56.852	85.278	113.704	142.130	170.556	198.981	227.407	255.833
.8	28.519	57.037	85.556	114.074	142.593	171.111	199.630	228.148	256.667
.9	28.611	57.222	85.833	114.444	143.056	171.667	200.278	228.889	257.500
31.0	28.704	57.407	86.111	114.815	143.519	172.222	200.926	229.630	258.333
.1	28.796	57.593	86.389	115.185	143.981	172.778	201.574	230.370	259.167
.2	28.889	57.778	86.667	115.556	144.444	173.333	202.222	231.111	260.000
.3	28.981	57.963	86.944	115 926	144.907	173.889	202.870	231.852	260.833
.4	29.074	58.148	87.222	116.296	145.370	174.444	203.519	232.593	261.667
.5	29.167	58.333	87.500	116.667	145.833	175.000	204.167	233.333	262.500
.6	29.259	58.519	87.778	117.037	146.296	175.556	204.815	234.074	263.333
.7	29.352	58.704	88.056	117.407	146.759	176.111	205.463	234.815	264.167
.8	29.444	58.889	88.333	117.778	147.222	176.667	206.111	235.556	265.000
.9	29.537	59.074	88.611	118.148	147.685	177.222	206.759	236.296	265.833
32.0	29.630	59.259	88.889	118.519	148.148	177.778	207.407	237.037	266.667
.1	29.722	59.444	89.167	118.889	148.611	178.333	208.056	237.778	267.500
.2	29.815	59.630	89.444	119.259	149.074	178.889	208.704	238.519	268.333
.3	29.907	59.815	89.722	119.630	149.537	179.444	209.352	239.259	269.167
.4	30.000	60.000	90.000	120.000	150.000	180.000	210.000	240.000	270.000
.5	30.093	60.185	90.278	120.370	150.463	180.556	210.648	240.741	270.833
.6	30.185	60.370	90.556	120.741	150.926	181.111	211.296	241.481	271.667
.7	30.278	60.556	90.833	121.111	151.389	181.667	211.944	242.222	272.500
.8	30.370	60.741	91.111	121.481	151.852	182.222	212.593	242.963	273.333
.9	30.463	60.926	91.389	121.852	152.315	182.778	213.241	243.704	274.167
33.0	30.556	61.111	91.667	122.222	152.778	183.333	213.889	244.444	275.000
.1	30.648	61.296	91.944	122.593	153.241	183.889	214.537	245.185	275.833
.2	30.741	61.481	92.222	122.963	153.704	184.444	215.185	245.926	276.667
.3	30.833	61.667	92.500	123.333	154.167	185.000	215.833	246.667	277.500
.4	30.926	61.852	92.778	123.704	154.630	185.556	216.481	247.407	278.333
.5	31.019	62.037	93.056	124.074	155.093	186.111	217.130	248.148	279.167
.6	31.111	62.222	93.333	124.444	155.556	186.667	217.778	248.889	280.000
.7	31.204	62.407	93.611	124.815	156.019	187.222	218.426	249.630	280.833
.8	31.296	62.593	93.889	125.185	156.481	187.778	219.074	250.370	281.667
.9	31.389	62.778	94.167	125.556	156.944	188.333	219.722	251.111	282.500
34.0	31.481	62.963	94.444	125.926	157.407	188.889	220.370	251.852	283.333
.1	31.574	63.148	94.722	126.296	157.870	189.444	221.019	252.593	284.167
.2	31.667	63.333	95.000	126.667	158.333	190.000	221.667	253.333	285.000
.3	31.759	63.519	95.278	127.037	158.796	190.556	222.315	254.074	285.833
.4	31.852	63.704	95.556	127.407	159.259	191.111	222.963	254.815	286.667
.5	31.944	63.889	95.833	127.778	159.722	191.667	223.611	255.556	287.500
.6	32.037	64.074	96.111	128.148	160.185	192.222	224.259	256.296	288.333
.7	32.130	64.259	96.389	128.519	160.648	192.778	224.907	257.037	289.167
.8	32.222	64.444	96.667	128.889	161.111	193.333	225.556	257.778	290.000
.9	32.315	64.630	96.944	129.259	161.574	193.889	226.204	258.519	290.833
35.0	32.407	64.815	97.222	129.630	162.037	194.444	226.852	259.259	291.667
.1	32.500	65.000	97.500	130.000	162.500	195.000	227.500	260.000	292.500
.2	32.593	65.185	97.778	130.370	162.963	195.556	228.148	260.741	293.333
.3	32.685	65.370	98.056	130.741	163.426	196.111	228.796	261.481	294.167
.4	32.778	65.556	98.333	131.111	163.889	196.667	229.444	262.222	295.000
.5	32.870	65.741	98.611	131.481	164.352	197.222	230.093	262.963	295.833
.6	32.963	65.926	98.889	131.852	164.815	197.778	230.741	263.704	296.667
[illegible]	[illegible].056	66.111	99.167	132.222	165.278	198.333	231.389	264.444	297.500
[illegible]	[illegible]148	66.296	99.444	132.593	165.741	198.889	232.037	265.185	298.333
[illegible]	[illegible]	66.481	99.722	132.963	166.204	199.444	232.685	265.926	299.1
[illegible]	[illegible]	66.667	100.000	133.333	166.667	200.000	233.333	266.667	300.

Hgt.	WIDTH.								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
36.1	33.426	66.852	100.278	133.704	167.130	200.556	233.981	267.407	300.833
.2	33.519	67.037	100.556	134.074	167.593	201.111	234.630	268.148	301.667
.3	33.611	67.222	100.833	134.444	168.056	201.667	235.278	268.889	302.500
.4	33.704	67.407	101.111	134.815	168.519	202.222	235.926	269.630	303.333
.5	33.796	67.593	101.389	135.185	168.981	202.778	236.574	270.370	304.167
.6	33.889	67.778	101.667	135.556	169.444	203.333	237.222	271.111	305.000
.7	33.981	67.963	101.944	135.926	169.907	203.889	237.870	271.852	305.833
.8	34.074	68.148	102.222	136.296	170.370	204.444	238.519	272.593	306.667
.9	34.167	68.333	102.500	136.667	170.833	205.000	239.167	273.333	307.500
37.0	34.259	68.519	102.778	137.037	171.296	205.556	239.815	274.074	308.333
.1	34.352	68.704	103.056	137.407	171.759	206.111	240.463	274.815	309.167
.2	34.444	68.889	103.333	137.778	172.222	206.667	241.111	275.556	310.000
.3	34.537	69.074	103.611	138.148	172.685	207.222	241.759	276.296	310.833
.4	34.630	69.259	103.889	138.519	173.148	207.778	242.407	277.037	311.667
.5	34.722	69.444	104.167	138.889	173.611	208.333	243.056	277.778	312.500
.6	34.815	69.630	104.444	139.259	174.074	208.889	243.704	278.519	313.333
.7	34.907	69.815	104.722	139.630	174.537	209.444	244.352	279.259	314.167
.8	35.000	70.000	105.000	140.000	175.000	210.000	245.000	280.000	315.000
.9	35.093	70.185	105.278	140.370	175.463	210.556	245.648	280.741	315.833
38.0	35.185	70.370	105.556	140.741	175.926	211.111	246.296	281.481	316.667
.1	35.278	70.556	105.833	141.111	176.389	211.667	246.944	282.222	317.500
.2	35.370	70.741	106.111	141.481	176.852	212.222	247.593	282.963	318.333
.3	35.463	70.926	106.389	141.852	177.315	212.778	248.241	283.704	319.167
.4	35.556	71.111	106.667	142.222	177.778	213.333	248.889	284.444	320.000
.5	35.648	71.296	106.944	142.593	178.241	213.889	249.537	285.185	320.833
.6	35.741	71.481	107.222	142.963	178.704	214.444	250.185	285.926	321.667
.7	35.833	71.667	107.500	143.333	179.167	215.000	250.833	286.667	322.500
.8	35.926	71.852	107.778	143.704	179.630	215.556	251.481	287.407	323.333
.9	36.019	72.037	108.056	144.074	180.093	216.111	252.130	288.148	324.167
39.0	36.111	72.222	108.333	144.444	180.556	216.667	252.778	288.889	325.000
.1	36.204	72.407	108.611	144.815	181.019	217.222	253.426	289.630	325.833
.2	36.296	72.593	108.889	145.185	181.481	217.778	254.074	290.370	326.667
.3	36.389	72.778	109.167	145.556	181.944	218.333	254.722	291.111	327.500
.4	36.481	72.963	109.444	145.926	182.407	218.889	255.370	291.852	328.333
.5	36.574	73.148	109.722	146.296	182.870	219.444	256.019	292.593	329.167
.6	36.667	73.333	110.000	146.667	183.333	220.000	256.667	293.333	330.000
.7	36.759	73.519	110.278	147.037	183.796	220.556	257.315	294.074	330.833
.8	36.852	73.704	110.556	147.407	184.259	221.111	257.963	294.815	331.667
.9	36.944	73.889	110.833	147.778	184.722	221.667	258.611	295.556	332.500
40.0	37.037	74.074	111.111	148.148	185.185	222.222	259.259	296.296	333.333
.1	37.130	74.259	111.389	148.519	185.648	222.778	259.907	297.037	334.167
.2	37.222	74.444	111.667	148.889	186.111	223.333	260.556	297.778	335.000
.3	37.315	74.630	111.944	149.259	186.574	223.889	261.204	298.519	335.833
.4	37.407	74.815	112.222	149.630	187.037	224.444	261.852	299.259	336.667
.5	37.500	75.000	112.500	150.000	187.500	225.000	262.500	300.000	337.500
.6	37.593	75.185	112.778	150.370	187.963	225.556	263.148	300.741	338.333
.7	37.685	75.370	113.056	150.741	188.426	226.111	263.796	301.481	339.167
.8	37.778	75.556	113.333	151.111	188.889	226.667	264.444	302.222	340.000
.9	37.870	75.741	113.611	151.481	189.352	227.222	265.093	302.963	340.833
41.0	37.963	75.926	113.889	151.852	189.815	227.778	265.741	303.704	341.667
.1	38.056	76.111	114.167	152.222	190.278	228.333	266.389	304.444	342.500
.2	38.148	76.296	114.444	152.593	190.741	228.889	267.037	305.185	343.333
.3	38.241	76.481	114.722	152.963	191.204	229.444	267.685	305.926	244.167
.4	38.333	76.667	115.000	153.333	191.667	230.000	268.333	306.667	345.000
.5	38.426	76.852	115.278	153.704	192.130	230.556	268.981	307.407	345.833
.6	38.519	77.037	115.556	154.074	192.593	231.111	269.630	308.148	346.667
.7	38.611	77.222	115.833	154.444	193.056	231.667	270.278	308.889	347.500
.8	38.704	77.407	116.111	154.815	193.519	232.222	270.926	309.630	348.333
.9	38.796	77.593	116.389	155.185	193.981	232.778	271.574	310.370	349.1
2.0	38.889	77.778	116.667	155.556	194.444	233.333	272.222	311.111	350.

Hgt.	1	2	3	4	5	6	7	8	9
	WIDTH.								
42.1	38.981	77.963	116.944	155.926	194.907	233.889	272.870	311.852	350.833
.2	39.074	78.148	117.222	156.296	195.370	234.444	273.519	312.593	351.667
.3	39.167	78.333	117.500	156.667	195.833	235.000	274.167	313.333	352.500
.4	39.259	78.519	117.778	157.037	196.296	235.556	274.815	314.074	353.333
.5	39.352	78.704	118.056	157.407	196.759	236.111	275.463	314.815	354.167
.6	39.444	78.889	118.333	157.778	197.222	236.667	276.111	315.556	355.000
.7	39.537	79.074	118.611	158.148	197.685	237.222	276.759	316.296	355.833
.8	39.630	79.259	118.889	158.519	198.148	237.778	277.407	317.037	356.667
.9	39.722	79.444	119.167	158.889	198.611	238.333	278.056	317.778	357.500
43.0	39.815	79.630	119.444	159.259	199.074	238.889	278.704	318.519	358.333
.1	39.907	79.815	119.722	159.630	199.537	239.444	279.352	319.259	359.167
.2	40.000	80.000	120.000	160.000	200.000	240.000	280.000	320.000	360.000
.3	40.093	80.185	120.278	160.370	200.463	240.556	280.648	320.741	360.833
.4	40.185	80.370	120.556	160.741	200.926	241.111	281.296	321.481	361.667
.5	40.278	80.556	120.833	161.111	201.389	241.667	281.944	322.222	362.500
.6	40.370	80.741	121.111	161.481	201.852	242.222	282.593	322.963	363.333
.7	40.463	80.926	121.389	161.852	202.315	242.778	283.241	323.704	364.167
.8	40.556	81.111	121.667	162.222	202.778	243.333	283.889	324.444	365.000
.9	40.648	81.296	121.944	162.593	203.241	243.889	284.537	325.185	365.833
44.0	40.741	81.481	122.222	162.963	203.704	244.444	285.185	325.926	366.667
.1	40.833	81.667	122.500	163.333	204.167	245.000	285.833	326.667	367.500
.2	40.926	81.852	122.778	163.704	204.630	245.556	286.481	327.407	368.333
.3	41.019	82.037	123.056	164.074	205.093	246.111	287.130	328.148	369.167
.4	41.111	82.222	123.333	164.444	205.556	246.667	287.778	328.889	370.000
.5	41.204	82.407	123.611	164.815	206.019	247.222	288.426	329.630	370.833
.6	41.296	82.593	123.889	165.185	206.481	247.778	289.074	330.370	371.667
.7	41.389	82.778	124.167	165.556	206.944	248.333	289.722	331.111	372.500
.8	41.481	82.963	124.444	165.926	207.407	248.889	290.370	331.852	373.333
.9	41.574	83.148	124.722	166.296	207.870	249.444	291.019	332.593	374.167
45.0	41.667	83.333	125.000	166.667	208.333	250.000	291.667	333.333	375.000
.1	41.759	83.519	125.278	167.037	208.796	250.556	292.315	334.074	375.833
.2	41.852	83.704	125.556	167.407	209.259	251.111	292.963	334.815	376.667
.3	41.944	83.889	125.833	167.778	209.722	251.667	293.611	335.556	377.500
.4	42.037	84.074	126.111	168.148	210.185	252.222	294.259	336.296	378.333
.5	42.130	84.259	126.389	168.519	210.648	252.778	294.907	337.037	379.167
.6	42.222	84.444	126.667	168.889	211.111	253.333	295.556	337.778	380.000
.7	42.315	84.630	126.944	169.259	211.574	253.889	296.204	338.519	380.833
.8	42.407	84.815	127.222	169.630	212.037	254.444	296.852	339.259	381.667
.9	42.500	85.000	127.500	170.000	212.500	255.000	297.500	340.000	382.500
46.0	42.593	85.185	127.778	170.370	212.963	255.556	298.148	340.741	383.333
.1	42.685	85.370	128.056	170.741	213.426	256.111	298.796	341.481	384.167
.2	42.778	85.556	128.333	171.111	213.889	256.667	299.444	342.222	385.000
.3	42.870	85.741	128.611	171.481	214.352	257.222	300.093	342.963	385.833
.4	42.963	85.926	128.889	171.852	214.815	257.778	300.741	343.704	386.667
.5	43.056	86.111	129.167	172.222	215.278	258.333	301.389	344.444	387.500
.6	43.148	86.296	129.444	172.593	215.741	258.889	302.037	345.185	388.333
.7	43.241	86.481	129.722	172.963	216.204	259.444	302.685	345.926	389.167
.8	43.333	86.667	130.000	173.333	216.667	260.000	303.333	346.667	390.000
.9	43.426	86.852	130.278	173.704	217.130	260.556	303.981	347.407	390.833
47.0	43.519	87.037	130.556	174.074	217.593	261.111	304.630	348.148	391.667
.1	43.611	87.222	130.833	174.444	218.056	261.667	305.278	348.889	392.500
.2	43.704	87.407	131.111	174.815	218.519	262.222	305.926	349.630	393.333
.3	43.796	87.593	131.389	175.185	218.981	262.778	306.574	350.370	394.167
.4	43.889	87.778	131.667	175.556	219.444	263.333	307.222	351.111	395.000
.5	43.981	87.963	131.944	175.926	219.907	263.889	307.870	351.852	395.833
.6	44.074	88.148	132.222	176.296	220.370	264.444	308.519	352.593	396.667
.7	44.167	88.333	132.500	176.667	220.833	265.000	309.167	353.333	397.500
.8	44.259	88.519	132.778	177.037	221.296	265.556	309.815	354.074	398.333
[illegible]	[illegible].352	88.704	133.056	177.407	221.759	266.111	310.463	354.815	399.167
[illegible]	[illegible]444	88.889	133.333	177.778	222.222	266.667	311.111	355.556	400.00

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
48.1	44.537	89.074	133.611	178.148	222.685	267.222	311.759	356.296	400.833
.2	44.630	89.259	133.889	178.519	223.148	267.778	312.407	357.037	401.667
.3	44.722	89.444	134.167	178.889	223.611	268.333	313.056	357.778	402.500
.4	44.815	89.630	134.444	179.259	224.074	268.889	313.704	358.519	403.333
.5	44.907	89.815	134.722	179.630	224.537	269.444	314.352	359.259	404.167
.6	45.000	90.000	135.000	180.000	225.000	270.000	315.000	360.000	405.000
.7	45.093	90.185	135.278	180.370	225.463	270.556	315.648	360.741	405.833
.8	45.185	90.370	135.556	180.741	225.926	271.111	316.296	361.481	406.667
.9	45.278	90.556	135.833	181.111	226.389	271.667	316.944	352.222	407.500
49.0	45.370	90.741	136.111	181.481	226.852	272.222	317.593	362.963	408.333
.1	45.463	90.926	136.389	181.852	227.315	272.778	318.241	363.704	409.167
.2	45.556	91.111	136.667	182.222	227.778	273.333	318.889	364.444	410 000
.3	45.648	91.296	136.944	182.593	228.241	273.889	319.537	365.185	410.833
.4	45.741	91.481	137.222	182.963	228.704	274.444	320.185	365.926	411.667
.5	45.833	91.667	137.500	183.333	229.167	275.000	320.833	366.667	412.500
.6	45.926	91.852	137.778	183.704	229.630	275.556	321.481	367.407	413.333
.7	46.019	92.037	138.056	184.074	230.093	276.111	322.130	368.148	414.167
.8	46.111	92.222	138.333	184.444	230.556	276.667	322.778	368.889	415.000
.9	46.204	92.407	138.611	184.815	231.019	277.222	323.426	369.630	415.833
50.0	46.296	92.593	138.889	185.185	231.481	277.778	324.074	370.370	416.667
.1	46.389	92.778	139.167	185.556	231.944	278.333	324.722	371.111	417.500
.2	46.481	92.963	139.444	185.926	232.407	278.889	325.370	371.852	418.333
.3	46.574	93.148	139.722	186.296	232.870	279.444	326.019	372.593	419.167
.4	46.667	93.333	140.000	186.667	233.333	280.000	326.667	373.333	420.000
.5	46.759	93.519	140.278	187.037	233.796	280.556	327.315	374 074	420.833
.6	46.852	93.704	140.556	187.407	234.259	281.111	327.963	374.815	421.667
.7	46.944	93.889	140.833	187.778	234.722	281.667	328.611	375.556	422.500
.8	47.037	94.074	141.111	188.148	235.185	282.222	329.259	376.296	423.333
.9	47.130	94.259	141.389	188.519	235.648	282.778	329.907	377.037	424.167
51.0	47.222	94.444	141.667	188.889	236.111	283.333	330.556	377.778	425.000
.1	47.315	94.630	141.944	189.259	236.574	283.889	331.204	378.519	425.833
.2	47.407	94.815	142.222	189.630	237.037	284.444	331.852	379.259	426.667
.3	47.500	95.000	142.500	190.000	237.500	285.000	332.500	380.000	427.500
.4	47.593	95.185	142.778	190.370	237.963	285.556	333.148	380.741	428.333
.5	47.685	95.370	143.056	190.741	238.426	286.111	333.796	381.481	429.167
.6	47.778	95.556	143.333	191.111	238.889	286.667	334.444	382.222	430.000
.7	47.870	95.741	143.611	191.481	239.352	287.222	335.093	382.963	430.833
.8	47.963	95.926	143.889	191.852	239.815	287.778	335.741	383.704	431.667
.9	48.056	96.111	144.167	192.222	240.278	288.333	336.389	384.444	432.500
52.0	48.148	96.296	144.444	192.593	240.741	288.889	337.037	385.185	433.333
.1	48.241	96.481	144.722	192.963	241.204	289.444	337.685	385.926	434.167
.2	48.333	96.667	145.000	193.333	241.667	290.000	338.333	386.667	435.000
.3	48.426	96.852	145.278	193.704	242.130	290.556	338.981	387.407	435.833
.4	48.519	97.037	145.556	194.074	242.593	291.111	339.630	388.148	436.667
.5	48.611	97.222	145.833	194.444	243.056	291.667	340.278	388.889	437.500
.6	48.704	97.407	146.111	194.815	243.519	292.222	340.926	389.630	438.333
.7	48.796	97.593	146.389	195.185	243.981	292.778	341.574	390.370	439.167
.8	48.889	97.778	146.667	195.556	244.444	293.333	342.222	391.111	440.000
.9	48.981	97.963	146.944	195.926	244.907	293.889	342.870	391.852	440.833
53.0	49.074	98.148	147.222	196.296	245.370	294.444	343.519	392.593	441.667
.1	49.167	98.333	147.500	196.667	245.833	295.000	344.167	393.333	442.500
.2	49.259	98.519	147.778	197.037	246.296	295.556	344.815	394.074	443.333
.3	49.352	98.704	148.056	197.407	246.759	296.111	345.463	394.815	444.167
.4	49.444	98.889	148.333	197.778	247.222	296.667	346.111	395.556	445.000
.5	49.537	99.074	148.611	198.148	247.685	297.222	346.759	396.296	445.833
.6	49.630	99.259	148.889	198.519	248.148	297.778	347 407	397.037	446.667
.7	*49.722*	*99.444*	*149.167*	198.889	248 611	298.333	348.056	397.778	447.500
.8	*49.815*	*99.630*	*149.444*	199.259	249.074	298.889	348.704	398.519	448.333
.9	*49.907*	*99.815*	*149.722*	199.630	249.537	299.444	349.352	399.259	449.1
54.0	*50.000*	*100.000*	*150.000*	200.000	250.000	300.000	350.000	400.000	4

TABLE XXXI.—TRIANGULAR PRISMS

CU. YDS. PER 50 FT.

Hgt.	WIDTH.								
	1	2	3	4	5	6	7	8	9
54.1	50.093	100.185	150.278	200.370	250.463	300.556	350.648	400.741	450.833
.2	50.185	100.370	150.556	200.741	250.926	301.111	351.296	401.481	451.667
.3	50.278	100.556	150.833	201.111	251.389	301.667	351.944	402.222	452.500
.4	50.370	100.741	151.111	201.481	251.852	302.222	352.593	402.963	453.333
.5	50.463	100.926	151.389	201.852	252.315	302.778	353.241	403.704	454.167
.6	50.556	101.111	151.667	202.222	252.778	303.333	353.889	404.444	455.000
.7	50.648	101.296	151.944	202.593	253.241	303.889	354.537	405.185	455.833
.8	50.741	101.481	152.222	202.963	253.704	304.444	355.185	405.926	456.667
.9	50.833	101.667	152.500	203.333	254.167	305.000	355.833	406.667	457.500
55.0	50.926	101.852	152.778	203.704	254.630	305.556	356.481	407.407	458.333
.1	51.019	102.037	153.056	204.074	255.093	306.111	357.130	408.148	459.167
.2	51.111	102.222	153.333	204.444	255.556	306.667	357.778	408.889	460.000
.3	51.204	102.407	153.611	204.815	256.019	307.222	358.426	409.630	460.833
.4	51.296	102.593	153.889	205.185	256.481	307.778	359.074	410.370	461.667
.5	51.389	102.778	154.167	205.556	256.944	308.333	359.722	411.111	462.500
.6	51.481	102.963	154.444	205.926	257.407	308.889	360.370	411.852	463.333
.7	51.574	103.148	154.722	206.296	257.870	309.444	361.019	412.593	464.167
8	51 667	103.333	155.000	206.667	258.333	310.000	361.667	413.333	465.000
.9	51.759	103.519	155.278	207.037	258.796	310.556	362.315	414.074	465.833
56.0	51.852	103.704	155.556	207.407	259.259	311.111	362.963	414.815	466.667
.1	51.944	103.889	155 833	207.778	259.722	311.667	363.611	415.556	467.500
.2	52.037	104.074	156.111	208.148	260.185	312.222	364.259	416.296	468.333
.3	52.130	104.259	156.389	208.519	260.648	312.778	364.907	417.037	469.167
.4	52.222	104.444	156.667	208.889	261.111	313.333	365.556	417.778	470.000
.5	52.315	104.630	156.944	209.259	261.574	313.889	366.204	418.519	470.833
.6	52.407	104.815	157.222	209.630	252.037	314.444	366.852	419.259	471.667
.7	52.500	105.000	157.500	210.000	262.500	315.000	367.500	420.000	472.500
.8	52.593	105.185	157.778	210.370	262.963	315.556	368.148	420.741	473.333
.9	52.685	105.370	158.056	210.741	263.426	316.111	368.796	421.481	474.167
57.0	52.778	105.556	158.333	211.111	263.889	316.667	369.444	422.222	475.000
.1	52.870	105.741	158.611	211.481	264.352	317.222	370.093	422.963	475.833
.2	52.963	105.926	158.889	211.852	264.815	317.778	370.741	423.704	476.667
.3	53.056	106.111	159.167	212.222	265.278	318.333	371.389	424.444	477.500
.4	53.148	106.296	159.444	212.593	265.741	318.889	372.037	425.185	478.333
.5	53.241	106.481	159.722	212.963	266.204	319.444	372.685	425.926	479.167
.6	53.333	106.667	160.000	213.333	266.667	320.000	373.333	426.667	480.000
.7	53.426	106.852	160.278	213.704	267.130	320.556	373.981	427.407	480.833
.8	53.519	107.037	160.556	214.074	267.593	321.111	374.630	428.148	481.667
.9	53.611	107.222	160.833	214.444	268.056	321.667	375.278	428.889	482.500
58.0	53.704	107.407	161.111	214.815	268.519	322.222	375.926	429.630	483.333
.1	53.796	107.593	161.389	215.185	268.981	322.778	376.574	430.370	484.167
.2	53.889	107.778	161.667	215.556	269.444	323.333	377.222	431.111	485.000
.3	53.981	107.963	161.944	215.926	269.907	323.889	377.870	431.852	485.833
.4	54.074	108.148	162.222	216.296	270.370	324.444	378.519	432.593	486.667
.5	54.167	108.333	162.500	216.667	270.833	325.000	379.167	433.333	487.500
.6	54.259	108.519	162.778	217.037	271.296	325.556	379.815	434.074	488.333
.7	54.352	108.704	163.056	217.407	271.759	326.111	380.463	434.815	489.167
.8	54.444	108.889	163.333	217.778	272.222	326.667	381.111	435.556	490.000
.9	54.537	109.074	163.611	218.148	272.685	327.222	381.759	436.296	490.833
59.0	54.630	109.259	163.889	218.519	273.148	327.778	382 407	437.037	491.667
.1	54.722	109.444	164.167	218.889	273.611	328.333	383.056	437.778	492.500
.2	54.815	109.630	164.444	219.259	274.074	328.889	383.704	438.519	493.333
.3	54.907	109.815	164.722	219.630	274.537	329.444	384.352	439.259	494.167
.4	55.000	110.000	165.000	220.000	275.000	330.000	385.000	440.000	495.000
.5	*55.093*	*110.135*	165.278	220.370	275.463	330.556	385.648	440.741	495.833
.6	*55.185*	*110.370*	165.556	220.741	275.926	331.111	386.296	441.481	496.667
.7	*55.278*	*110.556*	165.833	221.111	276.389	331.667	386.944	442.222	497.500
[illegible]	[illegible]	*110.741*	166.111	221.481	276.852	332.222	387.593	442.963	498.333
[illegible]	[illegible]	*110.926*	166.389	221.852	277.315	332.778	388.241	443.704	499.
		111.111	166.667	222.222	277.778	333.333	388.889	444.444	500.

TABLE XXXII.—PRISMOIDAL CORRECTIONS

CU. YDS. PER 100 FT.

d–d′ D–D′	1	2	3	4	5	6	7	8	9
0.1	.031	.062	.093	.123	.154	.185	.216	.247	.278
.2	.062	.123	.185	.247	.309	.370	.432	.494	.556
.3	.093	.185	.278	.370	.463	.556	.648	.741	.833
.4	.123	.247	.370	.494	.617	.741	.864	.988	1.111
.5	.154	.309	.463	.617	.772	.926	1.080	1.235	1.389
.6	.185	.370	.556	.741	.926	1.111	1.296	1.481	1.667
.7	.216	.432	.648	.864	1.080	1.296	1.512	1.728	1.944
.8	.247	.494	.741	.988	1.235	1.481	1.728	1.975	2.222
.9	.278	.556	.833	1.111	1.389	1.667	1.944	2.222	2.500
1.0	.309	.617	.926	1.235	1.543	1.852	2.160	2.469	2.778
.1	.340	.679	1.019	1.358	1.698	2.037	2.377	2.716	3.056
.2	.370	.741	1.111	1.481	1.852	2.222	2.593	2.963	3.333
.3	.401	.802	1.204	1.605	2.006	2.407	2.809	3.210	3.611
.4	.432	.864	1.296	1.728	2.160	2.593	3.025	3.457	3.889
.5	.463	.926	1.389	1.852	2.315	2.778	3.241	3.704	4.167
.6	.494	.988	1.481	1.975	2.469	2.963	3.457	3.951	4.444
.7	.525	1.049	1.574	2.099	2.623	3.148	3.673	4.198	4.722
.8	.556	1.111	1.667	2.222	2.778	3.333	3.889	4.444	5.000
.9	.586	1.173	1.759	2.346	2.932	3.519	4.105	4.691	5.278
2.0	.617	1.235	1.852	2.469	3.086	3.704	4.321	4.938	5.556
.1	.648	1.296	1.944	2.593	3.241	3.889	4.537	5.185	5.833
.2	.679	1.358	2.037	2.716	3.395	4.074	4.753	5.432	6.111
.3	.710	1.420	2.130	2.840	3.549	4.259	4.969	5.679	6.389
.4	.741	1.481	2.222	2.963	3.704	4.444	5.185	5.926	6.667
.5	.772	1.543	2.315	3.086	3.858	4.630	5.401	6.173	6.944
.6	.802	1.605	2.407	3.210	4.012	4.815	5.617	6.420	7.222
.7	.833	1.667	2.500	3.333	4.167	5.000	5.833	6.667	7.500
.8	.864	1.728	2.593	3.457	4.321	5.185	6.049	6.914	7.778
.9	.895	1.790	2.685	3.580	4.475	5.370	6.265	7.160	8.056
3.0	.926	1.852	2.778	3.704	4.630	5.556	6.481	7.407	8.333
.1	.957	1.914	2.870	3.827	4.784	5.741	6.698	7.654	8.611
.2	.988	1.975	2.963	3.951	4.938	5.926	6.914	7.901	8.889
.3	1.019	2.037	3.056	4.074	5.093	6.111	7.130	8.148	9.167
.4	1.049	2.099	3.148	4.198	5.247	6.296	7.346	8.395	9.444
.5	1.080	2.160	3.241	4.321	5.401	6.481	7.562	8.642	9.722
.6	1.111	2.222	3.333	4.444	5.556	6.667	7.778	8.889	10.000
.7	1.142	2.284	3.426	4.568	5.710	6.852	7.994	9.136	10.278
.8	1.173	2.346	3.519	4.691	5.864	7.037	8.210	9.383	10.556
.9	1.204	2.407	3.611	4.815	6.019	7.222	8.426	9.630	10.833
4.0	1.235	2.469	3.704	4.938	6.173	7.407	8.642	9.877	11.111
.1	1.265	2.531	3.796	5.062	6.327	7.593	8.858	10.123	11.389
.2	1.296	2.593	3.889	5.185	6.481	7.778	9.074	10.370	11.667
.3	1.327	2.654	3.981	5.309	6.636	7.963	9.290	10.617	11.944
.4	1.358	2.716	4.074	5.432	6.790	8.148	9.506	10.864	12.222
.5	1.389	2.778	4.167	5.556	6.944	8.333	9.722	11.111	12.500
.6	1.420	2.840	4.259	5.679	7.099	8.519	9.938	11.358	12.778
.7	1.451	2.901	4.352	5.802	7.253	8.704	10.154	11.605	13.056
.8	1.481	2.963	4.444	5.926	7.407	8.889	10.370	11.852	13.333
.9	1.512	3.025	4.537	6.049	7.562	9.074	10.586	12.099	13.611
5.0	1.543	3.086	4.630	6.173	7.716	9.259	10.802	12.346	13.889
.1	1.574	3.148	4.722	6.296	7.870	9.444	11.019	12.593	14.167
.2	1.605	3.210	4.815	6.420	8.025	9.630	11.235	12.840	14.444
.3	1.636	3.272	4.907	6.543	8.179	9.815	11.451	13.086	14.722
.4	1.667	3.333	5.000	6.667	8.333	10.000	11.667	13.333	15.000
.5	1.698	3.395	5.093	6.790	8.488	10.185	11.883	13.580	15.278
.6	1.728	3.457	5.185	6.914	8.642	10.370	12.099	13.827	15.556
.7	1.759	3.519	5.278	7.037	8.796	10.556	12.315	14.074	15.833
.8	1.790	3.580	5.370	7.160	8.951	10.741	12.531	14.321	16.111
.9	1.821	3.642	5.463	7.284	9.105	10.926	12.747	14.568	16.
6.0	1.852	3.704	5.556	7.407	9.259	11.111	12.963	14.815	1

TABLE XXXII.—PRISMOIDAL CORRECTIONS
CU. YDS. PER 100 FT.

d–d′ D–D′	1	2	3	4	5	6	7	8	9
6.1	1.883	3.766	5.648	7.531	9.414	11.296	13.179	15.062	16.944
.2	1.914	3.827	5.741	7.654	9.568	11.481	13.395	15.309	17.222
.3	1.944	3.889	5.833	7.778	9.722	11.667	13.611	15.556	17.500
.4	1.975	3.951	5.926	7.901	9.877	11.852	13.827	15.802	17.778
.5	2.006	4.012	6.019	8.025	10.031	12.037	14.043	16.049	18.056
.6	2.037	4.074	6.111	8.148	10.185	12.222	14.259	16.296	18.333
.7	2.068	4.136	6.204	8.272	10.340	12.407	14.475	16.543	18.611
.8	2.099	4.198	6.296	8.395	10.494	12.593	14.691	16.790	18.889
.9	2.130	4.259	6.389	8.519	10.648	12.778	14.907	17.037	19.167
7.0	2.160	4.321	6.481	8.642	10.802	12.963	15.123	17.284	19.444
.1	2.191	4.383	6.574	8.766	10.957	13.148	15.340	17.531	19.722
.2	2.222	4.444	6.667	8.889	11.111	13.333	15.556	17.778	20.000
.3	2.253	4.506	6.759	9.012	11.265	13.519	15.772	18.025	20.278
.4	2.284	4.568	6.852	9.136	11.420	13.704	15.988	18.272	20.556
.5	2.315	4.630	6.944	9.259	11.574	13.889	16.204	18.519	20.833
.6	2.346	4.691	7.037	9.383	11.728	14.074	16.420	18.766	21.111
.7	2.377	4.753	7.130	9.506	11.883	14.259	16.636	19.012	21.389
.8	2.407	4.815	7.222	9.630	12.037	14.444	16.852	19.259	21.667
.9	2.438	4.877	7.315	9.753	12.191	14.630	17.067	19.506	21.944
8.0	2.469	4.938	7.407	9.877	12.346	14.815	17.284	19.753	22.222
.1	2.500	5.000	7.500	10.000	12.500	15.000	17.500	20.000	22.500
.2	2.531	5.062	7.593	10.123	12.654	15.185	17.716	20.247	22.778
.3	2.562	5.123	7.685	10.247	12.809	15.370	17.932	20.494	23.056
.4	2.593	5.185	7.778	10.370	12.963	15.556	18.148	20.741	23.333
.5	2.623	5.247	7.870	10.494	13.117	15.741	18.364	20.988	23.611
.6	2.654	5.309	7.963	10.617	13.272	15.926	18.580	21.235	23.889
.7	2.685	5.370	8.056	10.741	13.426	16.111	18.796	21.481	24.167
.8	2.716	5.432	8.148	10.864	13.580	16.296	19.012	21.728	24.444
.9	2.747	5.494	8.241	10.988	13.735	16.481	19.228	21.975	24.722
9.0	2.778	5.556	8.333	11.111	13.889	16.667	19.444	22.222	25.000
.1	2.809	5.617	8.426	11.235	14.043	16.852	19.660	22.469	25.278
.2	2.840	5.679	8.519	11.358	14.198	17.037	19.877	22.716	25.556
.3	2.870	5.741	8.611	11.481	14.352	17.222	20.093	22.963	25.833
.4	2.901	5.802	8.704	11.605	14.506	17.407	20.309	23.210	26.111
.5	2.932	5.864	8.796	11.728	14.660	17.593	20.525	23.457	26.389
.6	2.963	5.926	8.889	11.852	14.815	17.778	20.741	23.704	26.667
.7	2.994	5.988	8.981	11.975	14.969	17.963	20.957	23.951	26.944
.8	3.025	6.049	9.074	12.099	15.123	18.148	21.173	24.198	27.222
.9	3.056	6.111	9.167	12.222	15.278	18.333	21.389	24.444	27.500
10.0	3.086	6.173	9.259	12.346	15.432	18.519	21.605	24.691	27.778
.1	3.117	6.235	9.352	12.469	15.586	18.704	21.821	24.938	28.056
.2	3.148	6.296	9.444	12.593	15.741	18.889	22.037	25.185	28.333
.3	3.179	6.359	9.537	12.716	15.895	19.074	22.253	25.432	28.611
.4	3.210	6.420	9.630	12.840	16.049	19.259	22.469	25.679	28.889
.5	3.241	6.481	9.722	12.963	16.204	19.444	22.685	25.926	29.167
.6	3.272	6.543	9.815	13.086	16.359	19.630	22.901	26.173	29.444
.7	3.302	6.605	9.907	13.210	16.512	19.815	23.117	26.420	29.722
.8	3.333	6.667	10.000	13.333	16.667	20.000	23.333	26.667	30.000
.9	3.364	6.728	10.093	13.457	16.821	20.185	23.549	26.914	30.278
11.0	3.395	6.790	10.185	13.580	16.975	20.370	23.766	27.160	30.556
.1	3.426	6.852	10.278	13.704	17.130	20.556	23.981	27.407	30.833
.2	3.457	6.914	10.370	13.827	17.284	20.741	24.198	27.654	31.111
.3	3.488	6.975	10.463	13.951	17.438	20.926	24.414	27.901	31.389
.4	3.519	7.037	10.556	14.074	17.593	21.111	24.630	28.148	31.667
.5	3.549	7.099	10.648	14.198	17.747	21.296	24.846	28.395	31.944
.6	3.580	7.160	10.741	14.321	17.901	21.481	25.062	28.642	32.222
.7	3.611	7.222	10.833	14.444	18.056	21.667	25.278	28.889	32.500
.8	3.642	7.284	10.926	14.568	18.210	21.852	25.494	29.136	32.778
[illegible]	3.673	7.346	11.019	14.691	18.364	22.037	25.710	29.383	33.05
[illegible]	3.704	7.407	11.111	14.815	18.519	22.222	25.926	29.630	33.3

CU.YDS. PER 100 FT.

d–d′ D–D′	1	2	3	4	5	6	7	8	9
12.1	3.735	7.469	11.204	14.938	18.673	22.407	26.142	29.877	33.611
.2	3.766	7.531	11.296	15.062	18.827	22.593	26.359	30.123	33.889
.3	3.796	7.593	11.389	15.185	18.981	22.778	26.574	30.370	34.167
.4	3.827	7.654	11.481	15.309	19.136	22.963	26.790	30.617	34.444
.5	3.858	7.716	11.574	15.432	19.290	23.148	27.006	30.864	34.722
.6	3.889	7.778	11.667	15.556	19.444	23.333	27.222	31.111	35.000
.7	3.920	7.840	11.759	15.679	19.599	23.519	27.438	31.359	35.278
.8	3.951	7.901	11.852	15.802	19.753	23.704	27.654	31.605	35.556
.9	3.981	7.963	11.944	15.926	19.907	23.889	27.870	31.852	35.833
13.0	4.012	8.025	12.037	16.049	20.062	24.074	28.086	32.099	36.111
.1	4.043	8.086	12.130	16.173	20.216	24.259	28.302	32.346	36.389
.2	4.074	8.148	12.222	16.296	20.370	24.444	28.519	32.593	36.667
.3	4.105	8.210	12.315	16.420	20.525	24.630	28.735	32.840	36.944
.4	4.136	8.272	12.407	16.543	20.679	24.815	28.951	33.086	37.222
.5	4.167	8.333	12.500	16.667	20.833	25.000	29.167	33.333	37.500
.6	4.198	8.395	12.593	16.790	20.988	25.185	29.383	33.580	37.778
.7	4.228	8.457	12.685	16.914	21.142	25.370	29.599	33.827	38.056
.8	4.259	8.519	12.778	17.037	21.296	25.556	29.815	34.074	38.333
.9	4.290	8.580	12.870	17.160	21.451	25.741	30.031	34.321	38.611
14.0	4.321	8.642	12.963	17.284	21.605	25.926	30.247	34.568	38.889
.1	4.352	8.704	13.056	17.407	21.759	26.111	30.463	34.815	39.167
.2	4.383	8.766	13.148	17.531	21.914	26.296	30.679	35.062	39.444
.3	4.414	8.827	13.241	17.654	22.068	26.481	30.895	35.309	39.722
.4	4.444	8.889	13.333	17.778	22.222	26.667	31.111	35.556	40.000
.5	4.475	8.951	13.426	17.901	22.377	26.852	31.327	35.802	40.278
.6	4.506	9.012	13.519	18.025	22.531	27.037	31.543	36.049	40.556
.7	4.537	9.074	13.611	18.148	22.685	27.222	31.759	36.296	40.833
.8	4.568	9.136	13.704	18.272	22.840	27.407	31.975	36.543	41.111
.9	4.599	9.198	13.796	18.395	22.994	27.593	32.191	36.790	41.389
15.0	4.630	9.259	13.889	18.519	23.148	27.778	32.407	37.037	41.667
.1	4.660	9.321	13.981	18.642	23.302	27.963	32.623	37.284	41.944
.2	4.691	9.383	14.074	18.766	23.457	28.148	32.840	37.531	42.222
.3	4.722	9.444	14.167	18.889	23.611	28.333	33.056	37.778	42.500
.4	4.753	9.506	14.259	19.012	23.766	28.519	33.272	38.025	42.778
.5	4.784	9.568	14.352	19.136	23.920	28.704	33.488	38.272	43.056
.6	4.815	9.630	14.444	19.259	24.074	28.889	33.704	38.519	43.333
.7	4.846	9.691	14.537	19.383	24.228	29.074	33.920	38.766	43.611
.8	4.877	9.753	14.630	19.506	24.383	29.259	34.136	39.012	43.889
.9	4.907	9.815	14.722	19.630	24.537	29.444	34.352	39.259	44.167
16.0	4.938	9.877	14.815	19.753	24.691	29.630	34.568	39.506	44.444
.1	4.969	9.938	14.907	19.877	24.846	29.815	34.784	39.753	44.722
.2	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000
.3	5.031	10.062	15.093	20.123	25.154	30.185	35.216	40.247	45.278
.4	5.062	10.123	15.185	20.247	25.309	30.370	35.432	40.494	45.556
.5	5.093	10.185	15.278	20.370	25.463	30.556	35.648	40.741	45.833
.6	5.123	10.247	15.370	20.494	25.617	30.741	35.864	40.988	46.111
.7	5.154	10.309	15.463	20.617	25.772	30.926	36.080	41.235	46.389
.8	5.185	10.370	15.556	20.741	25.926	31.111	36.296	41.481	46.667
.9	5.216	10.432	15.648	20.864	26.080	31.296	36.512	41.728	46.944
17.0	5.247	10.494	15.741	20.988	26.235	31.481	36.728	41.975	47.222
.1	5.278	10.556	15.833	21.111	26.389	31.667	36.944	42.222	47.500
.2	5.309	10.617	15.926	21.235	26.543	31.852	37.160	42.469	47.778
.3	5.340	10.679	16.019	21.358	26.698	32.037	37.377	42.716	48.056
.4	5.370	10.741	16.111	21.481	26.852	32.222	37.593	42.963	48.333
.5	5.401	10.802	16.204	21.605	27.006	32.407	37.809	43.210	48.611
.6	5.432	10.864	16.296	21.728	27.160	32.593	38.025	43.457	48.889
.7	5.463	10.926	16.389	21.852	27.315	32.778	38.241	43.704	49.167
.8	5.494	10.988	16.481	21.975	27.469	32.963	38.457	43.951	49.44
.9	5.525	11.049	16.574	22.099	27.623	33.148	38.673	44.198	49.7
18.0	5.556	11.111	16.667	22.222	27.778	33.333	38.889	44.444	50.

TABLE XXXII.—PRISMOIDAL CORRECTIONS

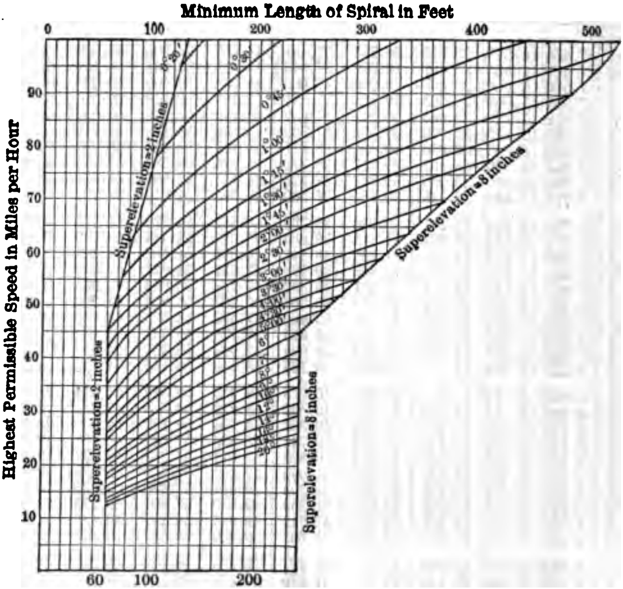
CU.YDS. PER 100 FT.

d–d′ D–D′	1	2	3	4	5	6	7	8	9
18.1	5.586	11.173	16.759	22.346	27.932	33.519	39.105	44.691	50.278
.2	5.617	11.235	16.852	22.469	28.086	33.704	39.321	44.938	50.556
.3	5.648	11.296	16.944	22.593	28.241	33.889	39.537	45.185	50.833
.4	5.679	11.358	17.037	22.716	28.395	34.074	39.753	45.432	51.111
.5	5.710	11.420	17.130	22.840	28.549	34.259	39.969	45.679	51.389
.6	5.741	11.481	17.222	22.963	28.704	34.444	40.185	45.926	51.667
.7	5.772	11.543	17.315	23.086	28.858	34.630	40.401	46.173	51.944
.8	5.802	11.605	17.407	23.210	29.012	34.815	40.617	46.420	52.222
.9	5.833	11.667	17.500	23.333	29.167	35.000	40.833	46.667	52.500
19.0	5.864	11.728	17.593	23,457	29.321	35.185	41.049	46.914	52.778
.1	5.895	11.790	17.685	23.580	29.475	35.370	41.265	47.160	53.056
.2	5.926	11.852	17.778	23.704	29.630	35.556	41.481	47.407	53.333
.3	5.957	11.914	17.870	23.827	29.784	35.741	41.698	47.654	53.611
.4	5.988	11.975	17.963	23.951	29.938	35.926	41.914	47.901	53.889
.5	6.019	12.037	18.056	24.074	30.093	36.111	42.130	48.148	54.167
.6	6.049	12.099	18.148	24.198	30.247	36.296	42.346	48.395	54.444
.7	6.080	12.160	18.241	24.321	30.401	36.481	42.562	48.642	54.722
.8	6.111	12.222	18.333	24.444	30.556	36.667	42.778	48.889	55.000
.9	6.142	12.284	18.426	24.568	30.710	36.852	42.994	49.136	55.278
20.0	6.173	12.346	18.519	24.691	30.864	37.037	43.210	49.383	55.556
.1	6.204	12.407	18.611	24.815	31.019	37.222	43.426	49.630	55.833
.2	6.235	12.469	18.704	24.938	31.173	37.407	43.642	49.877	56.111
.3	6.265	12.531	18.796	25.062	31.327	37.593	43.858	50.123	56.389
.4	6.296	12.593	18.889	25.185	31.481	37.778	44.074	50.370	56.667
.5	6.327	12.654	18.981	25.309	31.636	37.963	44.290	50.617	56.944
.6	6.359	12.716	19.074	25.432	31.790	38.148	44.506	50.864	57.222
.7	6.389	12.778	19.167	25.556	31.944	38.333	44.722	51.111	57.500
.8	6.420	12.840	19.259	25.679	32.099	38.519	44.938	51.359	57.778
.9	6.451	12.901	19.352	25.802	32.253	38.704	45.154	51.605	58.056
21.0	6.481	12.963	19.444	25.926	32.407	38.889	45.370	51.852	58.333
.1	6.512	13.025	19.537	26.049	32.562	39.074	45.586	52.099	58.611
.2	6.543	13.086	19.630	26.173	32.716	39.259	45.802	52.346	58.889
.3	6.574	13.148	19.722	26.296	32.870	39.444	46.019	52.593	59.167
.4	6.605	13.210	19.815	26.420	33.025	39.630	46.235	52.840	59.444
.5	6.636	13.272	19.907	26.543	33.179	39.815	46.451	53.086	59.722
.6	6.667	13.333	20.000	26.667	33.333	40.000	46.667	53.333	60.000
.7	6.698	13.396	20.093	26.790	33.488	40.185	46.883	53.580	60.278
.8	6.728	13.457	20.185	26.914	33.642	40.370	47.099	53.827	60.556
.9	6.759	13.519	20.278	27.037	33.796	40.556	47.315	54.074	60.833
22.0	6.790	13.580	20.370	27.160	33.951	40.741	47.531	54.321	61.111
.1	6.821	13.641	20.463	27.284	34.105	40.926	47.747	54.568	61.389
.2	6.852	13.704	20.556	27.407	34.259	41.111	47.963	54.815	61.667
.3	6.883	13.766	20.648	27.531	34.414	41.296	48.179	55.062	61.944
.4	6.914	13.827	20.741	27.654	34.568	41.481	48.395	55.309	62.222
.5	6.944	13.889	20.833	27.778	34.722	41.667	48.611	55.556	62.500
.6	6.975	13.951	20.926	27.901	34.877	41.852	48.827	55.802	62.778
.7	7.006	14.012	21.019	28.025	35.031	42.037	49.043	56.049	63.056
.8	7.037	14.074	21.111	28.148	35.185	42.222	49.259	56.296	63.333
.9	7.068	14.136	21.204	28.272	35.340	42.407	49.475	56.543	63.611
23.0	7.099	14.198	21.296	28.395	35.494	42.593	49.691	56.790	63.889
.1	7.130	14.259	21.389	28.519	35.648	42.778	49.907	57.037	64.167
.2	7.160	14.321	21.481	28.642	35.802	42.963	50.123	57.284	64.444
.3	7.191	14.383	21.574	28.766	35.957	43.148	50.340	57.531	64.722
.4	7.222	14.444	21.667	28.889	36.111	43.333	50.556	57.778	65.000
.5	7.253	14.506	21.759	29.012	36.265	43.519	50.772	58.025	65.278
.6	7.284	14.568	21.852	29.136	36.420	43.704	50.988	58.272	65.556
.7	7.315	14.630	21.944	29.259	36.574	43.889	51.204	58.519	65.833
.8	7.346	14.691	22.037	29.383	36.728	44.074	51.420	58.766	66.111
[illegible]	7.377	14.753	22.130	29.506	36.883	44.259	51.636	59.012	66.389
[illegible]	7.407	14.815	22.222	29.630	37.037	44.444	51.852	59.259	66.667

TABLE XXXII.—PRISMOIDAL CORRECTIONS
CU.YDS. PER 100 FT.

d-d'	1	2	3	4	5	6	7	8	9
D-D'									
24.1	7.438	14.877	22.315	29.753	37.191	44.630	52.068	59.506	66.944
.2	7.469	14.938	22.407	29.877	37.346	44.815	52.284	59.753	67.222
.3	7.500	15.000	22.500	30.000	37.500	45.000	52.500	60.000	67.500
.4	7.531	15.062	22.593	30.123	37.654	45.185	52.716	60.247	67.778
.5	7.562	15.123	22.685	30.247	37.809	45.370	52.932	60.494	68.056
.6	7.593	15.185	22.778	30.370	37.963	45.556	53.148	60.741	68.333
.7	7.623	15.247	22.870	30.494	38.117	45.741	53.364	60.988	68.611
.8	7.654	15.309	22.963	30.617	38.272	45.926	53.580	61.235	68.889
.9	7.685	15.370	23.056	30.741	38.426	46.111	53.796	61.481	69.167
25.0	7.716	15.432	23.148	30.864	38.580	46.296	54.012	61.728	69.444
.1	7.747	15.494	23.241	30.988	38.735	46.481	54.228	61.975	69.722
.2	7.778	15.556	23.333	31.111	38.889	46.667	54.444	62.222	70.000
.3	7.809	15.617	23.426	31.235	39.043	46.852	54.660	62.469	70.278
.4	7.840	15.679	23.519	31.358	39.198	47.037	54.877	62.716	70.556
.5	7.870	15.741	23.611	31.481	39.352	47.222	55.093	62.963	70.833
.6	7.901	15.802	23.704	31.605	39.506	47.407	55.309	63.210	71.111
.7	7.932	15.864	23.796	31.728	39.660	47.593	55.525	63.457	71.389
.8	7.963	15.926	23.889	31.852	39.815	47.778	55.741	63.704	71.667
.9	7.994	15.988	23.981	31.975	39.969	47.963	55.957	63.951	71.944
26.0	8.025	16.049	24.074	32.099	40.123	48.148	56.173	64.198	72.222
.1	8.056	16.111	24.167	32.222	40.278	48.333	56.389	64.444	72.500
.2	8.086	16.173	24.259	32.346	40.432	48.519	56.605	64.691	72.778
.3	8.117	16.235	24.352	32.469	40.586	48.704	56.821	64.938	73.056
.4	8.148	16.296	24.444	32.593	40.741	48.889	57.037	65.185	73.333
.5	8.179	16.358	24.537	32.716	40.895	49.074	57.253	65.432	73.611
.6	8.210	16.420	24.630	32.840	41.049	49.259	57.469	65.679	73.889
.7	8.241	16.481	24.722	32.963	41.204	49.444	57.685	65.926	74.167
.8	8.272	16.543	24.815	33.086	41.359	49.630	57.901	66.173	74.444
.9	8.302	16.605	24.907	33.210	41.512	49.815	58.117	66.420	74.722
27.0	8.333	16.667	25.000	33.333	41.667	50.000	58.333	66.667	75.000
.1	8.364	16.728	25.093	33.457	41.821	50.185	58.549	66.914	75.278
.2	8.395	16.790	25.185	33.580	41.975	50.370	58.766	67.160	75.556
.3	8.426	16.852	25.278	33.704	42.130	50.556	58.981	67.407	75.833
.4	8.457	16.914	25.370	33.827	42.284	50.741	59.198	67.654	76.111
.5	8.488	16.975	25.463	33.951	42.438	50.926	59.414	67.901	76.389
.6	8.519	17.037	25.556	34.074	42.593	51.111	59.630	68.148	76.667
.7	8.549	17.099	25.648	34.198	42.747	51.296	59.846	68.395	76.944
.8	8.580	17.160	25.741	34.321	42.901	51.481	60.062	68.642	77.222
.9	8.611	17.222	25.833	34.444	43.056	51.667	60.278	68.889	77.500
28.0	8.642	17.284	25.926	34.568	43.210	51.852	60.494	69.136	77.778
.1	8.673	17.346	26.019	34.691	43.364	52.037	60.710	69.383	78.056
.2	8.704	17.407	26.111	34.815	43.519	52.222	60.926	69.630	78.333
.3	8.735	17.469	26.204	34.938	43.673	52.407	61.142	69.877	78.611
.4	8.766	17.531	26.296	35.062	43.827	52.593	61.359	70.123	78.889
.5	8.796	17.593	26.389	35.185	43.981	52.778	61.574	70.370	79.167
.6	8.827	17.654	26.481	35.309	44.136	52.963	61.790	70.617	79.444
.7	8.858	17.716	26.574	35.432	44.290	53.148	62.006	70.864	79.722
.8	8.889	17.778	26.667	35.556	44.444	53.333	62.222	71.111	80.000
.9	8.920	17.840	26.759	35.679	44.599	53.519	62.438	71.359	80.278
29.0	8.951	17.901	26.852	35.802	44.753	53.704	62.654	71.605	80.556
.1	8.981	17.963	26.944	35.926	44.907	53.889	62.870	71.852	80.833
.2	9.012	18.025	27.037	36.049	45.062	54.074	63.086	72.099	81.111
.3	9.043	18.086	27.130	36.173	45.216	54.259	63.302	72.346	81.389
.4	9.074	18.148	27.222	36.296	45.370	54.444	63.519	72.593	81.667
.5	9.105	18.210	27.315	36.420	45.525	54.630	63.735	72.840	81.944
.6	9.136	18.272	27.407	36.543	45.679	54.815	63.951	73.086	82.222
.7	*9.167*	*18.333*	*27.500*	36.667	45.833	55.000	64.167	73.333	82.50
.8	*9.198*	*18.395*	*27.593*	36.790	45.988	55.185	64.383	73.580	82.
.9	*9.228*	*18.457*	*27.685*	36.914	46.142	55.370	64.599	73.827	83.
30.0	*9.259*	*18.519*	*27.778*	37.037	46.296	55.556	64.815	74.074	8

TABLE XXXIII.—MINIMUM LENGTH OF SPIRAL CURVE



Limiting Curves. For all curves which are liable to limit the speed of trains, the length of spiral should equal that indicated on the line marked "Superelevation = 8 inches." Longer spirals may be used provided the increased length does not adversely affect the degree of curve or seriously affect the cost of construction.

Minor Curves. For minor curves the length of spiral should never be less than that indicated by the diagram; an increase of about 50 per cent over the indicated length may be desirable where cost is not seriously affected.

Spirals need not be used when superelevation required for highest permissible speed is less than two inches.

TABLE XXXIV.—ELEMENTS OF THE SPIRAL OF CHORD-LENGTH, 100

n	Degree of Curve. D_s	Spiral Angle. s	Inclination of Chord to Axis of Y.	Latitude of Each Chord. 100 × cos Incl.	Sum of the Latitudes. y
0	0° 00′	0° 00′	0° 00′		
1	10	10	05	99.99989423	99.99989423
2	20	30	20	99.99830769	199.99820192
3	30	1	45	99.99143275	299.98963467
4	40	1 40	1 20	99.97292412	399.96255879
5	50	2 30	2 05	99.93390007	499.89645886
6	1	3 30	3	99.8629535	599.7594123
7	1 10	4 40	4 05	99.7461539	699.5055662
8	1 20	6	5 20	99.5670790	799.0726452
9	1 30	7 30	6 45	99.3068457	898.3794909
10	1 40	9 10	8 20	98.944164	997.3236549
11	1 50	11	10 05	98.455415	1095.779070
12	2	13	12	97.814760	1193.593830
13	2 10	15 10	14 05	96.994284	1290.588114
14	2 20	17 30	16 20	95.964184	1386.552298
15	2 30	20	18 45	94.693014	1481.245312
16	2 40	22 40	21 20	93.147975	1574.393287
17	2 50	25 30	24 05	91.295292	1665.688579
18	3	28 30	27	89.100650	1754.789229
19	3 10	31 40	30 05	86.529730	1841.318959
20	3 20	35	33 20	83.548780	1924.867739

n	Departure of Each Chord. 100 × sin Incl.	Sum of the Departures. x	Logarithm. log y	Logarithm. log x
1	.1454441	.1454441	1.9999995	9.1626960
2	.5817731	.7272172	2.3010261	9.8616641
3	1.3089593	2.0361765	2.4771063	0.3088154
4	2.3268960	4.3630725	2.6020194	0.6397924
5	3.6353009	7.9983734	2.6988800	0.9030017
6	5.233596	13.231969	2.7779771	1.1216244
7	7.120730	20.352699	2.8447911	1.3086220
8	9.294991	29.647690	2.9025862	1.4719909
9	11.75374	41.40143	2.9534598	1.6170153
10	14.49319	55.89462	2.9988361	1.7473701
11	17.50803	73.40265	3.0397231	1.8657117
12	20.79117	94.19382	3.0768567	1.9740224
13	24.33329	118.52711	3.1107877	2.0738177
14	28.12251	146.64962	3.1419362	2.1662811
15	32.14395	178.79357	3.1706269	2.2523519
16	36.37932	215.17289	3.1971131	2.3327875
17	40.80649	255.97938	3.2215938	2.4082049
18	45.39905	301.37843	3.2442250	2.4791121
19	50.12591	351.50434	3.2651291	2.5459307
20	54.95090	406.45524	3.2844009	2.6090128

n	Log $\frac{x}{y}$ = log tan i	Deflection Angle. i	R_s	n	Log $\frac{x}{y}$ = log tan i	Deflection Angle. i	R_s
1	7.1626964	0° 05′ 00.″ 00	34377.5	11	8.8259886	3° 49′ 56.″ 39	3125.36
2	7.5606380	0° 12′ 30.″ 00	17188.8	12	8.8971657	4° 30′ 43.″ 95	2864.93
3	7.8317091	0° 23′ 20.″ 00	11459.2	13	8.9630300	5° 14′ 50.″ 28	2644.[illegible]8
4	8.0377730	0° 37′ 29.″ 99	8594.42	14	9.0243449	6° 02′ 14.″ 93	2455.70
5	8.2041217	0° 54′ 59.″ 97	6875.55	15	9.0817250	6° 52′ 57.″ 31	2292.0
6	8.3436473	1° 15′ 49.″ 90	5729.65	16	9.1356744	7° 48′ 56.″ 71	2148.
7	8.4638309	1° 39′ 59.″ 75	4911.15	17	9.1866111	8° 44′ 12.″ 28	2022
8	8 5694047	2° 07′ 29.″ 45	4297.28	18	9.2348871	9° 44′ 42.″ 92	19
9	8.6635555	2° 38′ 18.″ 90	3819.83	19	9.2808016	10° 48′ 27.″ 44	1
10	8.7485340	3° 12′ 27.″ 95	3437.87	20	9.3246119	11° 55′ 24.″ 34	

Rule for Finding a Deflection

Read under the *heading* corresponding to the point at which the instrument stands, and on the *line* of the number of the point observed.

n	Inst. at S *i*	Inst. at 1 *i*	Inst. at 2 *i*	Inst. at 3 *i*	Inst. at 4 *i*	*n*
0	00′	05′	17′ 30″	36′ 40″	1° 02′ 30″	0
1	05	00	10	27 30	51 40	1
2	12 30″	10	00	15	37 30	2
3	23 20	22 30″	15	00	20	3
4	37 30	38 20	32 30	20	00	4
5	55 00	57 30	53 20	42 30	25	5
6	1° 15 50	1° 20 00	1° 17 30	1° 08 20	52 30	6
7	1 40 00	1 45 50	1 45 00	1 37 30	1 23 20	7
8	2 07 29	2 15 00	2 15 50	2 10 00	1 57 30	8
9	2 38 19	2 47 29	2 49 59	2 45 50	2 35 00	9
10	3 12 28	3 23 18	3 27 29	3 24 59	3 15 50	10
11	3 49 56	4 02 27	4 08 18	4 07 28	3 59 59	11
12	4 30 44	4 44 55	4 52 26	4 53 17	4 47 28	12
13	5 14 50	5 30 42	5 39 54	5 42 25	5 38 16	13
14	6 02 15	6 19 47	6 30 40	6 34 52	6 32 24	14
15	6 52 57	7 12 11	7 24 44	7 30 37	7 29 50	15
16	7 46 57	8 07 51	8 22 06	8 29 40	8 30 34	16
17	8 44 12	9 06 49	9 22 45	9 32 01	9 34 36	17
18	9 44 43	10 09 01	10 26 39	10 37 37	10 41 55	18
19	10 48 27	11 14 28	11 33 49	11 46 29	11 52 29	19
20	11 55 24	12 23 08	12 44 12	12 58 35	13 06 18	20

n	Inst. at 5 *i*	Inst. at 6 *i*	Inst. at 7 *i*	Inst. at 8 *i*	Inst. at 9 *i*	*n*
0	1° 35′ 00″	2° 14′ 10″	3° 00′ 00″	3° 52′ 31″	4° 51′ 41″	0
1	1 22 30	2 00 00	2 44 10	3 35 00	4 32 31	1
2	1 06 40	1 42 30	2 25 00	3 14 10	4 10 01	2
3	47 30	1 21 40	2 02 30	2 50 00	3 44 10	3
4	25	57 30	1 36 40	2 22 30	3 15 00	4
5	00	30	1 07 30	1 51 40	2 42 30	5
6	30	00	35	1 17 30	2 06 40	6
7	1 02 30	35	00	40	1 27 30	7
8	1 38 20	1 12 30	40	00	45	8
9	2 17 30	1 53 20	1 22 30	45	00	9
10	3 00 00	2 37 30	2 08 20	1 32 30	50	10
11	3 45 50	3 25 00	2 57 30	2 23 20	1 42 30	11
12	4 34 59	4 15 49	3 50 00	3 17 30	2 38 20	12
13	5 27 28	5 09 58	4 45 49	4 15 00	3 37 30	13
14	6 23 15	6 07 27	5 44 58	5 15 49	4 40 00	14
15	7 22 23	7 08 15	6 47 26	6 19 58	5 45 49	15
16	8 24 48	8 12 21	7 53 14	7 27 26	6 54 57	16
17	9 30 31	9 19 46	9 02 19	8 38 13	8 07 26	17
18	10 39 32	10 30 28	10 14 43	9 52 18	9 23 11	18
19	11 51 48	11 44 27	11 30 24	11 09 40	10 42 18	19
20	12 07 20	13 01 41	12 49 21	12 30 20	12 04 38	20

Rule for Finding a Deflection

Read under the *heading* corresponding to the point at which the instrument stands, and on the *line* of the number of the point observed.

n	Inst. at 10 *i*	Inst. at 11 *i*	Inst. at 12 *i*	Inst. at 13 *i*	Inst. at 14 *i*	Inst. at 15 *i*	*n*
0	5° 57′ 32″	7° 10′ 04″	8° 29′ 16″	9° 55′ 10″	11° 27′ 45″	13° 07′ 03″	0
1	5 36 42	6 47 33	8 05 05	9 29 18	11 00 13	12 37 49	1
2	5 12 31	6 21 42	7 37 34	9 00 06	10 29 20	12 05 16	2
3	4 45 01	5 52 32	7 06 43	8 27 35	9 55 08	11 29 23	3
4	4 14 10	5 20 01	6 32 32	7 51 44	9 17 36	10 50 10	4
5	3 40 00	4 44 10	5 55 01	7 12 32	8 36 45	10 07 37	5
6	3 02 30	4 05 00	5 14 11	6 30 02	7 52 33	9 21 45	6
7	2 21 40	3 22 30	4 30 00	5 44 11	7 05 02	8 32 34	7
8	1 37 30	2 36 40	3 42 30	4 55 00	6 14 11	7 40 02	8
9	50	1 47 30	2 51 40	4 02 30	5 20 00	6 44 11	9
10	00	55	1 57 30	3 06 40	4 22 30	5 45 01	10
11	55	00	1 00 00	2 07 30	3 21 40	4 42 30	11
12	1 52 30	1 00 00	00	1 05 00	2 17 30	3 36 40	12
13	2 53 20	2 02 30	1 05 00	00	1 10 00	2 27 30	13
14	3 57 30	3 08 20	2 12 30	1 10 00	00	1 15 00	14
15	5 05 00	4 17 30	3 23 20	2 22 30	1 15 00	00	15
16	6 15 49	5 29 59	4 37 30	3 38 20	2 32 30	1 20 00	16
17	7 29 57	6 45 48	5 54 59	4 57 30	3 53 20	2 42 30	17
18	8 47 24	8 04 57	7 15 48	6 19 59	5 17 30	4 08 20	18
19	10 08 10	9 27 24	8 39 56	7 45 48	6 44 59	5 37 30	19
20	11 32 14	10 53 09	10 07 23	9 14 56	8 15 48	7 09 59	20

n	Inst. at 16 *i*	Inst. at 17 *i*	Inst. at 18 *i*	Inst. at 19 *i*	Inst. at 20 *i*	*n*
0	14° 58′ 03″	16° 45′ 48″	18° 45′ 17″	20° 51′ 33″	23° 04′ 36″	0
1	14 22 09	16 13 11	18 10 59	20 15 32	22 26 52	1
2	13 47 54	15 37 15	17 33 21	19 36 11	21 45 48	2
3	13 10 20	14 57 59	16 52 23	18 53 31	21 01 25	3
4	12 29 26	14 15 24	16 08 05	18 07 31	20 13 42	4
5	11 45 12	13 29 29	15 20 28	17 18 12	19 22 40	5
6	10 57 39	12 40 14	14 29 32	16 25 33	18 28 19	6
7	10 06 46	11 47 41	13 35 17	15 29 36	17 30 39	7
8	9 12 34	10 51 47	12 37 42	14 30 20	16 29 40	8
9	8 15 03	9 52 35	11 36 49	13 27 44	15 25 23	9
10	7 14 11	8 50 03	10 32 36	12 21 50	14 17 46	10
11	6 10 01	7 44 12	9 25 03	11 12 36	13 06 51	11
12	5 02 30	6 35 01	8 14 12	10 00 04	11 52 37	12
13	3 51 40	5 22 30	7 00 01	8 44 12	10 35 04	13
14	2 37 30	4 06 40	5 42 30	7 25 01	9 14 12	14
15	1 20 00	2 47 30	4 21 40	6 02 30	7 50 01	15
16	00	1 25 00	2 57 30	4 36 40	6 22 30	16
17	1 25 00	00	1 30 00	3 07 30	4 51 40	17
18	2 52 30	1 30 00	00	1 35	3 17 30	18
19	4 23 20	3 02 30	1 35 00	00	1 40	19
20	5 57 30	4 38 20	3 12 30	1 40	00	20

DEGREE OF CURVE AND VALUES OF THE COORDINATES x AND y, FOR EACH CHORD-POINT OF THE SPIRAL FOR VARIOUS LENGTHS OF THE CHORD

CHORD-LENGTH = 10

n	nc	D_s	y	x	Log x
1	10	1° 40′ 00″	10.000	0.0145	8.162696
2	20	3 20 02	20.000	.0727	8.861664
3	30	5 00 06	29.999	.2036	9.308815
4	40	6 40 13	39.996	.4363	9.639792
5	50	8 20 26	49.990	.7998	9.903002
6	60	10 00 45	59.976	1.323	0.121624
7	70	11 41 12	69.951	2.035	0.308622
8	80	13 21 48	79.907	2.965	0.471991
9	90	15 02 34	89.838	4.140	0.617015
10	100	16 43 31	99.732	5.589	0.747370
11	110	18 24 42	109.578	7.840	0.865712
12	120	20 06 07	119.359	9.419	0.974022
13	130	21 47 48	129.059	11.853	1.073818
14	140	23 29 46	138.655	14.655	1.166281
15	150	25 12 02	148.125	17.879	1.252352
16	160	26 54 39	157.439	21.517	1.332788
17	170	28 37 38	166.569	25.598	1.408205
18	180	30 21 01	175.479	30.138	1.479112
19	190	32 04 48	184.132	35.150	1.545931
20	200	33 49 02	192.487	40.646	1.609013
		35 33 46			

c. CHORD-LENGTH = 11

n	nc	D_s	y	x	Log x
1	11	1° 30′ 55″	11.000	0.0160	8.204089
2	22	3 01 50	22.000	.0800	8.903057
3	33	4 32 48	32.999	.2240	9.350208
4	44	6 03 48	43.996	.4799	9.681185
5	55	7 34 52	54.989	.8798	9.944394
6	66	9 06 01	65.974	1.456	0.163017
7	77	10 37 16	76.946	2.239	0.350015
8	88	12 08 37	87.898	3.261	0.513384
9	99	13 40 06	98.822	4.554	0.658408
10	110	15 11 44	109.706	6.148	0.788763
11	121	16 43 31	120.536	8.074	0.907104
12	132	18 15 29	131.295	10.361	1.015415
13	143	19 47 39	141.965	13.038	1.115210
14	154	21 20 01	152.521	16.131	1.207674
15	165	22 52 38	162.937	19.667	1.293745
16	176	24 25 29	173.183	23.669	1.374180
17	187	25 58 36	183.226	28.158	1.449598
18	198	27 32 01	193.027	33.152	1.520505
19	209	29 05 45	202.545	38.665	1.587323
20	220	30 39 48	211.735	44.710	1.650405
		32 14 11			

c. CHORD-LENGTH = 12

n	nc	D_s	y	x	Log x
1	12	1° 23′ 20″	12.000	0.0175	8.241877
2	24	2 46 41	24.000	.0873	8.940845
3	36	4 10 03	35.999	.2443	9.387997
4	48	5 33 28	47.996	.5236	9.718974
5	60	6 56 55	59.988	.9598	9.982183
6	72	8 20 26	71.971	1.588	0.200806
7	84	9 44 01	83.941	2.442	0.387803
8	96	11 07 42	95.889	3.558	0.551172
9	108	12 31 28	107.806	4.968	0.696196
10	120	13 55 21	119.679	6.707	0.826551
11	132	15 19 22	131.493	8.808	0.944893
12	144	16 43 31	143.231	11.303	1.053204
13	156	18 07 48	154.871	14.223	1.152999
14	168	19 32 15	166.386	17.598	1.245462
15	180	20 56 53	177.749	21.455	1.331533
16	192	22 21 43	188.927	25.821	1.411969
17	204	23 46 44	199.883	30.718	1.487386
18	216	25 11 59	210.575	36.165	1.558293
19	228	26 37 28	220.958	42.181	1.625113
20	240	28 03 12	230.984	48.774	1.688194
		29 29 12			

c. CHORD-LENGTH = 13

n	nc	D_s	y	x	Log x
1	13	1° 16′ 55″	13.000	0.0189	8.276639
2	26	2 33 52	26.000	.0945	8.975607
3	39	3 50 49	38.999	.2647	9.422759
4	52	5 07 48	51.995	.5672	9.753736
5	65	6 24 49	64.987	1.040	0.016945
6	78	7 41 53	77.969	1.720	0.235568
7	91	8 59 00	90.936	2.646	0.422565
8	104	10 16 12	103.879	3.854	0.585934
9	117	11 33 28	116.789	5.382	0.730959
10	130	12 50 49	129.652	7.266	0.861313
11	143	14 08 16	142.451	9.542	0.979655
12	156	15 25 50	155.167	12.245	1.087966
13	169	16 43 30	167.776	15.409	1.187761
14	182	18 01 18	180.252	19.064	1.280224
15	195	19 19 14	192.562	23.243	1.366295
16	208	20 37 20	204.671	27.972	1.446731
17	221	21 55 34	216.540	33.277	1.522148
18	234	23 14 00	228.123	39.179	1.593055
19	247	24 32 35	239.871	45.696	1.659874
20	260	25 51 23	250.233	52.839	1.722956
		27 10 23			

c. CHORD-LENGTH = 14

n	nc	D_s	y	x	Log x
1	14	1° 11′ 26″	14.000	0.0204	8.308824
2	28	2 22 52	28.000	.1018	9.007792
3	42	3 34 19	41.999	.2851	9.454943
4	56	4 45 48	55.995	.6108	9.785920
5	70	5 57 18	69.986	1.120	0.049130
6	84	7 08 51	83.966	1.852	0.267752
7	98	8 20 26	97.931	2.849	0.454750
8	112	9 32 04	111.870	4.151	0.618119
9	126	10 43 47	125.773	5.796	0.763143
10	140	11 55 33	139.625	7.825	0.893496
11	154	13 07 24	153.409	10.276	1.011840
12	168	14 19 20	167.103	13.187	1.120156
13	182	15 31 22	180.682	16.594	1.219946
14	196	16 43 29	194.117	20.531	1.312409
15	210	17 55 44	207.374	25.031	1.398480
16	224	19 06 05	220.415	30.124	1.478915
17	238	20 20 34	233.196	35.837	1.554333
18	252	21 33 11	245.670	42.193	1.625240
19	266	22 45 56	257.785	49.211	1.692059
20	280	23 58 51	269.481	56.908	1.755141
		25 11 55			

c. CHORD-LENGTH = 15

n	nc	D_s	y	x	Log x
1	15	1° 06′ 40″	15.000	0.0218	8.338787
2	30	2 13 20	30.000	.1091	9.037755
3	45	3 20 02	44.998	.3054	9.484907
4	60	4 26 44	59.994	.6545	9.815884
5	75	5 33 28	74.984	1.200	0.079093
6	90	6 40 13	89.964	1.985	0.297716
7	105	7 47 01	104.926	3.056	0.484718
8	120	8 53 51	119.861	4.447	0.648082
9	135	10 00 45	134.757	6.210	0.793107
10	150	11 07 41	149.599	8.384	0.923461
11	165	12 14 41	164.367	11.010	1.041808
12	180	13 21 47	179.039	14.129	1.150114
13	195	14 28 56	193.588	17.779	1.249909
14	210	15 36 09	207.983	21.997	1.342372
15	225	16 43 28	222.187	26.819	1.428443
16	240	17 50 54	236.159	32.276	1.508879
17	255	18 58 25	249.853	38.397	1.584296
18	270	20 06 02	263.218	45.207	1.655208
19	285	21 13 47	276.198	52.726	1.722092
[illegible]	300	22 21 39	288.730	60.968	1.785104
		23 29 48			

b. CHORD-LENGTH = 16

n	nc	D_s	y	x	Log x
1	16	1° 02′ 30″	16.000	0.0233	8.366816
2	32	2 05 00	32.000	.1164	9.065784
3	48	3 07 31	47.998	.3258	9.512935
4	64	4 10 03	63.994	.6981	9.843912
5	80	5 12 36	79.983	1.280	0.107122
6	96	6 15 11	95.961	2.117	0.325744
7	112	7 17 47	111.921	3.256	0.512742
8	128	8 20 26	127.852	4.744	0.676111
9	144	9 23 07	143.741	6.624	0.821135
10	160	10 25 51	159.572	8.943	0.951490
11	176	11 28 37	175.325	11.744	1.069832
12	192	12 31 28	190.975	15.071	1.178142
13	208	13 34 21	206.494	18.964	1.277938
14	224	14 37 20	221.848	23.464	1.370401
15	240	15 40 21	236.999	28.607	1.456472
16	256	16 43 28	251.903	34.428	1.536907
17	272	17 46 40	266.510	40.957	1.612325
18	288	18 49 57	280.766	48.221	1.683232
19	304	19 53 20	294.611	56.241	1.750051
20	320	20 56 49	307.979	65.032	1.813133
		22 00 23			

c. CHORD-LENGTH = 17

n	nc	D_s	y	x	Log x
1	17	0° 58′ 49″	17.000	0.0247	8.393145
2	34	1 57 38	34.000	.1236	9.092118
3	51	2 56 27	50.998	.3461	9.539264
4	68	3 55 19	67.994	.7417	9.870241
5	85	4 54 12	84.982	1.360	0.133451
6	102	5 53 06	101.959	2.249	0.352073
7	119	6 52 00	118.916	3.460	0.539071
8	136	7 50 57	135.842	5.040	0.702440
9	153	8 49 55	152.725	7.038	0.847464
10	170	9 48 56	169.545	9.502	0.977819
11	187	10 48 00	186.282	12.478	1.096161
12	204	11 47 07	202.911	16.013	1.204471
13	221	12 46 15	219.400	20.150	1.304267
14	238	13 45 27	235.714	24.930	1.396730
15	255	14 44 44	251.812	30.395	1.482801
16	272	15 44 03	267.647	36.579	1.563236
17	289	16 43 27	283.167	43.516	1.638654
18	306	17 42 56	298.314	51.234	1.709561
19	323	18 42 29	313.024	59.756	1.776380
20	340	19 42 07	327.228	69.097	1.839482
		20 41 49			

c. CHORD-LENGTH = 18

n	*nc*	D_s	*y*	*x*	Log *x*
1	18	0° 55′ 33″	18.000	0.0262	8.417968
2	36	1 51 07	36.000	.1309	9.116937
3	54	2 46 40	53.998	.3665	9.564088
4	72	3 42 16	71.993	.7853	9.895065
5	90	4 37 51	89.981	1.440	0.158274
6	108	5 33 28	107.957	2.382	0.376897
7	126	6 29 05	125.911	3.663	0.563894
8	144	7 24 45	143.833	5.337	0.727263
9	162	8 20 26	161.708	7.452	0.872288
10	180	9 16 08	179.518	10.061	1.002643
11	198	10 11 54	197.240	13.212	1.120984
12	216	11 07 41	214.847	16.955	1.229295
13	234	12 03 31	232.306	21.335	1.329090
14	252	12 59 24	249.579	26.397	1.421554
15	270	13 55 20	266.624	32.183	1.507624
16	288	14 51 18	283.391	38.731	1.588060
17	306	15 47 20	299.824	46.076	1.663477
18	324	16 43 27	315.862	54.248	1.734385
19	342	17 39 37	331.437	63.271	1.801203
20	360	18 35 51	346.476	73.161	1.864285
		19 32 08			

c. CHORD-LENGTH = 19

n	*nc*	D_s	*y*	*x*	Log *x*
1	19	0° 52′ 38″	19.000	0.0276	8.441450
2	38	1 45 16	38.000	.1382	9.140418
3	57	2 37 54	56.998	.3869	9.587569
4	76	3 30 34	75.993	.8290	9.918546
5	95	4 23 13	94.980	1.520	0.181755
6	114	5 15 54	113.954	2.514	0.400378
7	133	6 08 36	132.906	3.867	0.587376
8	152	7 01 19	151.824	5.633	0.750744
9	171	7 54 03	170.692	7.866	0.895769
10	190	8 46 49	189.491	10.620	1.026124
11	209	9 39 36	208.198	13.947	1.144465
12	228	10 32 26	226.783	17.897	1.252776
13	247	11 25 18	245.212	22.520	1.352571
14	266	12 18 12	263.445	27.863	1.445035
15	285	13 11 09	281.437	33.971	1.531105
16	304	14 04 09	299.135	40.883	1.611541
17	323	14 57 11	316.481	48.636	1.686958
[illegible]	342	15 50 16	333.410	57.262	1.757866
[illegible]	[illegible]	16 43 25	349.851	66.788	1.824684
[illegible]	[illegible]	17 36 38	365.725	77.226	1.887768
		18 29 54			

c. CHORD-LENGTH = 20

n	nc	D_s	y	x	Log x
1	20	0° 50′ 00″	20.000	0.0291	8.463726
2	40	1 40 00	40.000	.1454	9.162694
3	60	2 30 01	59.998	.4072	9.609845
4	80	3 20 02	79.993	.8726	9.940822
5	100	4 10 03	99.979	1.600	0.204032
6	120	5 00 05	119.952	2.646	0.422654
7	140	5 50 08	139.901	4.071	0.609652
8	160	6 40 13	159.815	5.930	0.773021
9	180	7 30 18	179.676	8.280	0.918045
10	200	8 20 26	199.465	11.179	1.048400
11	220	9 10 34	219.156	14.681	1.166742
12	240	10 00 44	238.719	18.839	1.275052
13	260	10 50 56	258.118	23.705	1.374848
14	280	11 41 10	277.310	29.330	1.467311
15	300	12 31 26	296.249	35.759	1.553382
16	320	13 21 45	314.879	43.035	1.633817
17	340	14 12 06	333.138	51.196	1.709235
18	360	15 02 29	350.958	60.276	1.780142
19	380	15 52 55	368.264	70.301	1.846961
20	400	16 43 25	384.974	81.290	1.910043
		17 33 58			

c. CHORD-LENGTH = 21

n	nc	D_s	y	x	Log x
1	21	0° 47′ 37″	21.000	0.0305	8.484915
2	42	1 35 14	42.000	.1527	9.183883
3	63	2 22 52	62.998	.4276	9.631035
4	84	3 10 30	83.992	.9162	9.962012
5	105	3 58 08	104.978	1.680	0.225221
6	126	4 45 47	125.949	2.779	0.443844
7	147	5 33 27	146.896	4.274	0.630841
8	168	6 21 08	167.805	6.226	0.794210
9	189	7 08 50	188.660	8.694	0.939235
10	210	7 56 33	209.438	11.738	1.069589
11	231	8 44 18	230.114	15.415	1.187931
12	252	9 32 03	250.655	19.781	1.296242
13	273	10 19 51	271.023	24.891	1.396037
14	294	11 07 40	291.176	30.796	1.488500
15	315	11 55 31	311.062	37.547	1.574571
16	336	12 43 24	330.623	45.186	1.655007
17	357	13 31 20	349.795	53.756	1.730424
18	378	14 19 17	368.506	63.289	1.801331
19	399	15 07 17	386.677	73.816	1.868150
20	420	15 55 19	404.222	85.356	1.931232
		16 43 26			

c. CHORD-LENGTH = 22

n	nc	D_s	y	x	Log s
1	22	45′ 27″	22.000	0.0320	8.505119
2	44	1° 30 53	44.000	.1600	9.204087
3	66	2 16 22	65.998	.4480	9.651238
4	88	3 01 50	87.992	.9599	9.982215
5	110	3 47 18	109.977	1.760	0.245424
6	132	4 32 48	131.947	2.911	0.464047
7	154	5 18 18	153.891	4.478	0.651045
8	176	6 03 48	175.796	6.522	0.814414
9	198	6 49 19	197.643	9.108	0.959438
10	220	7 34 51	219.411	12.297	1.089798
11	242	8 20 25	241.071	16.149	1.208134
12	264	9 06 00	262.591	20.723	1.316445
13	286	9 51 36	283.929	26.076	1.416240
14	308	10 37 13	305.042	32.263	1.508704
15	330	11 22 53	325.874	39.335	1.594775
16	352	12 08 34	346.367	47.338	1.675210
17	374	12 54 16	366.451	56.315	1.750628
18	396	13 40 01	386.054	66.303	1.821585
19	418	14 25 49	405.090	77.331	1.888353
		15 11 40			

c. CHORD-LENGTH = 23

n	nc	D_s	y	x	Log s
1	23	0° 43′ 29″	23.000	0.0335	8.524424
2	46	1 26 58	46.000	.1673	9.223392
3	69	2 10 26	68.998	.4683	9.670543
4	92	2 53 56	91.991	1.004	0.001520
5	115	3 37 26	114.976	1.840	0.264729
6	138	4 20 56	137.945	3.043	0.483352
7	161	5 04 26	160.886	4.681	0.670350
8	184	5 47 58	183.787	6.819	0.833719
9	207	6 31 30	206.627	9.522	0.978743
10	230	7 15 04	229.384	12.856	1.109098
11	253	7 58 38	252.029	16.883	1.227439
12	276	8 42 13	274.527	21.665	1.335750
13	299	9 25 49	296.835	27.261	1.435545
14	322	10 09 27	318.907	33.729	1.528009
15	345	10 53 06	340.686	41.123	1.614080
16	368	11 36 47	362.110	49.490	1.694515
17	391	12 20 29	383.108	58.875	1.769933
18	414	13 04 13	403.602	69.317	1.840840
		13 47 59			

c. CHORD-LENGTH = 24

n	nc	D_s	y	x	Log s
1	24	41′ 40″	24.000	0.0349	8.542907
2	48	1° 23 20	48.000	.1745	9.241875
3	72	2 05 00	71.998	.4887	9.689027
4	96	2 46 41	95.991	1.047	0.020004
5	120	3 28 22	119.975	1.920	0.283213
6	144	4 10 03	143.942	3.176	0.501836
7	168	4 51 45	167.881	4.885	0.688833
8	192	5 33 28	191.777	7.115	0.852202
9	216	6 15 10	215.611	9.936	0.997226
10	240	6 56 54	239.358	13.415	1.127581
11	264	7 38 39	262.987	17.617	1.245923
12	288	8 20 25	286.463	22.607	1.354234
13	312	9 02 12	309.741	28.446	1.454029
14	336	9 44 00	332.773	35.196	1.546492
[illegible]	360	10 25 48	355.499	42.910	1.632563
[illegible]	384	11 07 39	377.854	51.641	1.712999
[illegible]	408	11 49 31	399.765	61.435	1.788416
		12 31 25			

c. CHORD-LENGTH = 25

n	nc	D_s	y	x	Log x
1	25	0° 40′ 00″	25.000	0.0364	8.560636
2	50	1 20 00	50.000	.1818	9.259604
3	75	2 00 00	74.997	.5090	9.706755
4	100	2 40 01	99.991	1.091	0.037732
5	125	3 20 02	124.974	2.000	0.300942
6	150	4 00 03	149.940	3.308	0.519564
7	175	4 40 04	174.876	5.088	0.706562
8	200	5 20 06	199.768	7.412	0.869931
9	225	6 00 09	224.595	10.350	1.014955
10	250	6 40 13	249.331	13.974	1.145310
11	275	7 20 17	273.945	18.351	1.263652
12	300	8 00 22	298.398	23.548	1.371962
13	325	8 40 28	322.647	29.632	1.471758
14	350	9 20 35	346.638	36.662	1.564221
15	375	10 00 43	370.311	44.698	1.650292
16	400	10 40 52	393.598	53.793	1.730727
17	425	11 21 03	416.421	63.995	1.806145
		12 01 16			

c. CHORD-LENGTH = 26

n	nc	D_s	y	x	Log x
1	26	0° 38′ 28″	26.000	0.0378	8.577669
2	52	1 16 56	52.000	.1891	9.276637
3	78	1 55 24	77.997	.5294	9.723789
4	104	2 33 52	103.990	1.134	0.054766
5	130	3 12 20	129.973	2.080	0.317975
6	156	3 50 48	155.937	3.440	0.536598
7	182	4 29 18	181.871	5.292	0.723595
8	208	5 07 48	207.759	7.708	0.886964
9	234	5 46 18	233.579	10.764	1.031989
10	260	6 24 48	259.304	14.533	1.162348
11	286	7 03 20	284.903	19.085	1.280685
12	312	7 41 52	310.334	24.490	1.388996
13	338	8 20 25	335.553	30.817	1.488791
14	364	8 58 59	360.504	38.129	1.581254
15	390	9 37 33	385.124	46.486	1.667325
16	416	10 16 09	409.341	55.945	1.747761
		10 54 47			

c. CHORD-LENGTH = 27

n	nc	D_s	y	x	Log x
1	27	0° 37′ 02″	27.000	0.0393	8.594060
2	54	1 14 04	54.000	.1963	9.293028
3	81	1 51 07	80.997	.5498	9.740179
4	108	2 28 10	107.990	1.178	0.071156
5	135	3 05 12	134.972	2.160	0.334365
6	162	3 42 15	161.935	3.573	0.552988
7	189	4 19 19	188.866	5.495	0.739986
8	216	4 56 23	215.750	8.005	0.903355
9	243	5 33 28	242.562	11.178	1.048379
10	270	6 10 32	269.277	15.092	1.178734
11	297	6 47 38	295.860	19.819	1.297075
12	324	7 24 44	322.270	25.432	1.405388
13	351	8 01 51	348.459	32.002	1.505181
14	378	8 38 59	374.369	39.595	1.597645
15	405	9 16 07	399.936	48.274	1.683716
		9 53 16			

c. CHORD-LENGTH = 28

n	nc	D_s	y	x	Log x
1	28	0° 35′ 42″	28.000	0.0407	8.609854
2	56	1 11 26	55.999	.2036	9.308822
3	84	1 47 08	83.997	.5701	9.755973
4	112	2 22 52	111.990	1.222	0.086950
5	140	2 58 36	139.971	2.240	0.350160
6	168	3 34 19	167.933	3.705	0.568782
7	196	4 10 03	195.862	5.699	0.755780
8	224	4 45 48	223.740	8.301	0.919149
9	252	5 21 32	251.546	11.592	1.064173
10	280	5 57 17	279.251	15.650	1.194528
11	308	6 33 03	306.818	20.553	1.312870
12	336	7 08 50	334.206	26.374	1.421180
13	364	7 44 36	361.365	33.188	1.520976
14	392	8 20 24	388.235	41.062	1.613439
15	410	8 56 13	414.748	50.062	1.699510
		9 32 04			

c. CHORD-LENGTH = 29

n	nc	D_s	y	x	Log x
1	29	0° 34′ 29″	29.000	0.0422	8.625094
2	58	1 08 58	57.999	.2109	9.324062
3	87	1 43 27	86.997	.5905	9.771213
4	116	2 17 56	115.989	1.265	0.102190
5	145	2 52 26	144.970	2.320	0.365400
6	174	3 26 55	173.930	3.837	0.584022
7	203	4 01 26	202.857	5.902	0.771020
8	232	4 35 56	231.731	8.598	0.934389
9	261	5 10 26	260.530	12.006	1.079413
10	290	5 44 57	289.224	16.209	1.209768
11	319	6 19 29	317.776	21.287	1.328110
12	348	6 54 01	346.142	27.316	1.436420
13	377	7 28 34	374.271	34.373	1.536216
14	406	8 03 07	402.100	42.528	1.628679
		8 37 40			

c. CHORD-LENGTH = 30

n	nc	D_s	y	x	Log x
1	30	0° 33′ 20″	30.000	0.0436	8.639817
2	60	1 06 40	59.999	.2182	9.338785
3	90	1 40 00	89.997	.6108	9.785937
4	120	2 13 20	119.989	1.309	0.116914
5	150	2 46 41	149.969	2.400	0.380123
6	180	3 20 02	179.928	3.970	0.598746
7	210	3 53 22	209.852	6.106	0.785743
8	240	4 26 44	239.722	8.894	0.949112
9	270	5 00 05	269.514	12.420	1.094137
10	300	5 33 27	299.197	16.768	1.224491
11	330	6 06 49	328.734	22.021	1.342833
[illegible]	[illegible]	6 40 12	358.078	28.258	1.451144
[illegible]	[illegible]	7 13 36	387.176	35.558	1.550939
[illegible]	[illegible]	7 47 00	415.965	43.995	1.643402
		8 20 25			

c. CHORD-LENGTH = 31

n	nc	D_s	y	x	Log x
1	31	0° 32′ 15″	31.000	0.0451	8.654058
2	62	1 04 31	61.999	.2254	9.353026
3	93	1 36 47	92.997	.6312	9.800177
4	124	2 09 02	123.988	1.353	0.131154
5	155	2 41 18	154.968	2.479	0.394363
6	186	3 13 34	185.925	4.102	0.612986
7	217	3 45 50	216.847	6.309	0.799984
8	248	4 18 07	247.713	9.191	0.963353
9	279	4 50 24	278.498	12.834	1.108377
10	310	5 22 41	309.170	17.327	1.238732
11	341	5 54 59	339.692	22.755	1.357073
12	372	6 27 17	370.014	29.200	1.465384
13	403	6 59 35	400.082	36.743	1.565179
		7 31 53			

c. CHORD-LENGTH = 32

n	nc	D_s	y	x	Log x
1	32	0° 31′ 15″	32.000	0.0465	8.667846
2	64	1 02 30	63.999	.2327	9.366814
3	96	1 33 45	95.997	.6516	9.813965
4	128	2 05 00	127.988	1.396	0.144942
5	160	2 36 16	159.967	2.559	0.408152
6	192	3 07 31	191.923	4.234	0.626774
7	224	3 38 47	223.842	6.513	0.813772
8	256	4 10 03	255.703	9.487	0.977141
9	288	4 41 19	287.481	13.248	1.122165
10	320	5 12 36	319.144	17.886	1.252520
11	352	5 43 53	350.649	23.489	1.370862
12	384	6 15 10	381.950	30.142	1.479172
13	416	6 46 28	412.988	37.929	1.578968
		7 17 46			

c. CHORD-LENGTH = 33

n	nc	D_s	y	x	Log x
1	33	0° 30′ 19″	33.000	0.0480	8.681210
2	66	1 00 36	65.999	.2400	9.380178
3	99	1 30 55	98.997	.6719	9.827329
4	132	2 01 13	131.988	1.440	0.158306
5	165	2 31 32	164.966	2.639	0.421516
6	198	3 01 50	197.921	4.367	0.640138
7	231	3 32 09	230.837	6.716	0.827136
8	264	4 02 28	263.694	9.784	0.990505
9	297	4 32 48	296.465	13.662	1.135529
10	330	5 03 07	329.117	18.445	1.265884
11	363	5 33 27	361.607	24.223	1.384228
12	396	6 03 47	393.886	31.084	1.492538
13	429	6 34 07	425.872	39.114	1.592332
		7 04 29			

c. CHORD-LENGTH = 34

n	*nc*	*D*s	*y*	*x*	Log *x*
1	34	0° 29′ 25″	34.000	0.0495	8.694175
2	68	0 58 49	67.999	.2473	9.393142
3	102	1 28 14	101.996	.6923	9.840294
4	136	1 57 39	135.987	1.483	0.171271
5	170	2 27 04	169.965	2.719	0.434481
6	204	2 56 29	203.918	4.499	0.653108
7	238	3 25 55	237.832	6.920	0.840101
8	272	3 55 20	271.685	10.080	1.003470
9	306	4 24 46	305.449	14.076	1.148494
10	340	4 54 12	339.090	19.004	1.278849
11	374	5 23 38	372.565	24.957	1.397191
12	408	5 53 05	405.822	32.026	1.505501
		6 22 11			

c. CHORD-LENGTH = 35

n	*nc*	*D*s	*y*	*x*	Log *x*
1	35	0° 28′ 34″	35.000	0.0509	8.706764
2	70	0 57 09	69.999	.2545	9.405732
3	105	1 25 43	104.996	.7127	9.852883
4	140	1 54 17	139.987	1.527	0.183860
5	175	2 22 52	174.964	2.799	0.447070
6	210	2 51 27	209.916	4.631	0.665692
7	245	3 20 01	244.827	7.123	0.852690
8	280	3 48 36	279.675	10.377	1.016059
9	315	4 17 12	314.433	14.490	1.161083
10	350	4 45 47	349.063	19.563	1.291438
11	385	5 14 23	383.523	25.691	1.409780
12	420	5 43 00	417.758	32.968	1.518090
		6 09 36			

c. CHORD-LENGTH = 36

n	*nc*	*D*s	*y*	*x*	Log *x*
1	36	0° 27′ 47″	36.000	0.0524	8.718998
2	72	0 55 33	71.999	.2618	9.417967
3	108	1 23 20	107.996	.7330	9.865118
4	144	1 51 07	143.987	1.571	0.196095
5	180	2 18 54	179.963	2.879	0.459304
6	216	2 46 41	215.913	4.764	0.677927
7	252	3 14 28	251.822	7.327	0.864924
8	288	3 42 15	287.666	10.673	1.028293
9	324	4 10 03	323.417	14.905	1.173318
10	360	4 37 51	359.037	20.122	1.303673
	396	5 05 39	394.480	26.425	1.422014
	432	5 33 27	429.694	33.910	1.530325
		6 01 15			

c. CHORD-LENGTH = 37

n	nc	D_s	y	x	Log x
1	37	0° 27′ 02″	37.000	0.0538	8.730898
2	74	0 54 03	73.999	.2691	9.429866
3	111	1 21 05	110.996	.7534	9.877017
4	148	1 48 07	147.986	1.614	0.207994
5	185	2 15 09	184.962	2.959	0.471203
6	222	2 42 11	221.911	4.896	0.689826
7	259	3 09 13	258.817	7.530	0.876824
8	296	3 36 15	295.657	10.970	1.040193
9	333	4 03 17	332.400	15.319	1.185217
10	370	4 30 20	369.010	20.681	1.315572
11	407	4 57 23 5 24 26	405.438	27.159	1.433913

c. CHORD-LENGTH = 38

1	38	0° 26′ 19″	38.000	0.0553	8.742480
2	76	0 52 39	75.999	.2763	9.441448
3	114	1 18 57	113.996	.7737	9.888599
4	152	1 45 16	151.986	1.658	0.219576
5	190	2 11 35	189.961	3.039	0.482785
6	228	2 37 54	227.909	5.028	0.701408
7	266	3 04 14	265.812	7.734	0.888406
8	304	3 30 33	303.648	11.266	1.051774
9	342	3 56 53	341.384	15.733	1.196799
10	380	4 23 13	378.983	21.240	1.327154
11	418	4 49 33 5 15 53	416.396	27.893	1.445495

c. CHORD-LENGTH = 39

1	39	0° 25′ 38″	39.000	0.0567	8.753761
2	78	0 51 17	77.999	.2836	9.452729
3	117	1 16 55	116.996	.7941	9.899890
4	156	1 42 34	155.985	1.702	0.230857
5	195	2 08 13	194.960	3.119	0.494066
6	234	2 33 51	233.906	5.160	0.712689
7	273	2 59 30	272.807	7.938	0.899687
8	312	3 25 09	311.638	11.563	1.063055
9	351	3 50 48	350.368	16.147	1.208080
10	390	4 16 28	388.956	21.799	1.338435
11	429	4 42 07 5 07 46	427.354	28.627	1.456776

c. CHORD-LENGTH = 40

n	nc	D_s	y	x	Log x
1	40	0° 25′ 00″	40.000	0.0582	8.764756
2	80	0 50 00	79.999	.2909	9.463724
3	120	1 15 00	119.996	.8145	9.910875
4	160	1 40 00	159.985	1.745	0.241852
5	200	2 05 00	199.959	3.199	0.505062
6	240	2 30 01	239.904	5.293	0.723684
7	280	2 55 01	279.802	8.141	0.910682
8	320	3 20 01	319.629	11.859	1.074051
9	360	3 45 02	359.352	16.561	1.219075
10	400	4 10 03	398.929	22.358	1.349430
11	440	4 35 03	438.312	29.361	1.467772
		5 00 04			

c. CHORD-LENGTH = 41

1	41	0° 24′ 24″	41.000	0.0596	8.775480
2	82	0 48 47	81.999	.2982	9.474448
3	123	1 13 10	122.996	.8348	9.921599
4	164	1 37 34	163.985	1.789	0.252576
5	205	2 01 57	204.958	3.279	0.515786
6	246	2 26 21	245.901	5.425	0.734408
7	287	2 50 45	286.797	8.345	0.921406
8	328	3 15 09	327.620	12.156	1.084775
9	369	3 39 33	368.336	16.975	1.229799
10	410	4 03 57	408.903	22.917	1.360154
		4 28 21			

c. CHORD-LENGTH = 42

1	42	0° 23′ 49″	42.000	0.0611	8.785945
2	84	0 47 37	83.999	.3054	9.484913
3	126	1 11 26	125.996	.8552	9.932065
4	168	1 35 14	167.984	1.832	0.263042
5	210	1 59 02	209.957	3.359	0.526251
6	252	2 22 52	251.899	5.557	0.744874
7	294	2 46 41	293.792	8.548	0.931871
[illegible]	336	3 10 30	335.611	12.452	1.095240
[illegible]	378	3 34 19	377.319	17.389	1.240265
[illegible]	420	3 58 08	418.876	23.476	1.370619
		4 21 57			

c. CHORD-LENGTH = 43

n	nc	D_s	y	x	Log x
1	43	0° 23′ 15″	43.000	0.0625	8.796164
2	86	0 46 31	85.999	.3127	9.495133
3	129	1 09 46	128.996	.8755	9.942284
4	172	1 33 02	171.984	1.876	0.273261
5	215	1 56 17	214.955	3.439	0.536470
6	258	2 19 33	257.897	5.690	0.755093
7	301	2 42 48	300.787	8.752	0.942090
8	344	3 06 04	343.601	12.749	1.105459
9	387	3 29 20	386.303	17.803	1.250484
10	430	3 52 35	428.849	24.035	1.380839
		4 15 50			

c. CHORD-LENGTH = 44

1	44	0° 22′ 44″	44.000	0.0640	8.806149
2	88	0 45 27	87.999	.3200	9.505117
3	132	1 08 11	131.995	.8959	9.952268
4	176	1 30 55	175.984	1.920	0.283245
5	220	1 53 38	219.954	3.519	0.546454
6	264	2 16 22	263.894	5.822	0.765077
7	308	2 39 06	307.782	8.955	0.952075
8	352	3 01 50	351.592	13.045	1.115444
9	396	3 24 34	395.287	18.217	1.260468
10	440	3 47 18	438.822	24.594	1.390823
		4 10 02			

c. CHORD-LENGTH = 45

1	45	0° 22′ 13″	45.000	0.0655	8.815908
2	90	0 44 27	89.999	.3272	9.514877
3	135	1 06 40	134.995	.9163	9.962028
4	180	1 28 53	179.983	1.963	0.293005
5	225	1 51 07	224.953	3.599	0.556214
6	270	2 13 20	269.892	5.954	0.774837
7	315	2 35 34	314.778	9.159	0.961834
8	360	2 57 48	359.583	13.341	1.125203
9	405	3 20 01	404.271	18.631	1.270228
10	450	3 42 15	448.796	25.153	1.400583
		4 04 28			

c. CHORD-LENGTH = 46

1	46	0° 21′ 44″	46.000	0.0669	8.825454
2	92	0 43 29	91.999	.3345	9.524422
3	138	1 05 13	137.995	.9366	9.971573
4	184	1 26 58	183.983	2.007	0.302550
5	230	1 48 42	229.952	3.679	0.565759
6	276	2 10 26	275.889	6.087	0.784382
7	322	2 32 11	321.773	9.362	0.971380
8	368	2 53 56	367.573	13.638	1.134749
9	414	3 15 40	413.255	19.045	1.278773
10	460	3 37 24	458.769	25.712	1.410128
		3 59 08			

TABLE XXXVI.—DEGREES OF CURVES AND COORDINATES x AND y

c. CHORD-LENGTH = 47

n	nc	D_s	y	x	Log x
1	47	0° 21′ 16″	47.000	0.0684	8.834794
2	94	0 42 33	93.999	.3418	9.533762
3	141	1 03 50	140.995	.9570	9.980913
4	188	1 25 06	187.982	2.051	0.311899
5	235	1 46 23	234.951	3.759	0.575100
6	282	2 07 40	281.887	6.219	0.793722
7	329	2 28 57	328.768	9.566	0.980729
8	376	2 50 14	375.564	13.934	1.144089
9	423	3 11 31	422.238	19.459	1.289113
10	470	3 32 48	468.742	26.270	1.419468
		3 54 05			

c. CHORD-LENGTH = 48

1	48	0° 20′ 50″	48.000	0.0698	8.843937
2	96	0 41 40	95.999	.3491	9.542905
3	144	1 02 30	143.995	.9774	9.990057
4	192	1 23 20	191.982	2.094	0.321034
5	240	1 44 10	239.950	3.839	0.584243
6	288	2 05 00	287.885	6.351	0.802866
7	336	2 25 51	335.763	9.769	0.989863
8	384	2 46 41	383.555	14.231	1.153232
9	432	3 07 31	431.222	19.873	1.298256
		3 28 21			

c. CHORD-LENGTH = 49

1	49	0° 20′ 25″	49.000	0.0718	8.852892
2	98	0 40 49	97.999	.3563	9.551860
3	147	1 01 14	146.995	.9977	9.999011
4	196	1 21 38	195.982	2.138	0.329988
5	245	1 42 03	244.949	3.919	0.593198
6	294	2 02 27	293.882	6.484	0.811820
7	343	2 22 52	342.758	9.973	0.998818
8	392	2 43 17	391.546	14.527	1.162187
9	441	3 03 41	440.206	20.287	1.307211
		3 24 06			

c. CHORD-LENGTH = 50

1	50	0° 20′ 00″	50.000	0.0727	8.861666
2	100	0 40 00	99.999	.3636	9.560634
3	150	1 00 00	149.995	1.018	0.007785
4	200	1 20 00	199.981	2.182	0.338762
5	250	1 40 00	249.948	3.999	0.601972
[illegible]	300	2 00 00	299.880	6.616	0.820594
[illegible]	350	2 20 00	349.753	10.176	1.007592
[illegible]	400	2 40 01	399.536	14.824	1.170961
[illegible]	450	3 00 01	449.190	20.701	1.315985
		3 20 02			

s	cos *s*	log vers *s*	*R* 1° × vers *s*	sin *s*	log sin *s*	*s*
0° 10′	.99999	4.626422	.024	.00291	7.463726	0° 10′
0 30	.99996	5.580662	.218	.00873	7.940842	0 30
1 00	.99985	6.182714	.873	.01745	8.241855	1 00
1 40	.99958	6.626392	2.424	.02908	8.463665	1 40
2 30	.99905	6.978536	5.453	.04362	8.639680	2 30
3 30	.99813	7.270726	10.687	.06105	8.785675	3 30
4 40	.99668	7.520498	18.994	.08136	8.910404	4 40
6 00	.99452	7.738630	31.388	.10453	9.019235	6 00
7 30	.99144	7.932227	49.018	.13053	9.115698	7 30
9 10	.98723	8.106221	73.173	.15931	9.202234	9 10
11 00	.98163	8.264176	105.270	.19081	9.280599	11 00
13 00	.97437	8.408748	146.857	.22495	9.352088	13 00
15 10	.96517	8.541968	199.570	.26163	9.417684	15 10
17 30	.95372	8.665422	265.186	.30071	9.478142	17 30
20 00	.93969	8.780370	345.540	.34202	9.534052	20 00
22 40	.92276	8.887829	442.543	.38537	9.585877	22 40
25 30	.90259	8.988625	558.153	.43051	9.633984	25 30
28 30	.87882	9.083441	694.335	.47716	9.678663	28 30
31 40	.85112	9.172846	853.050	.52498	9.720140	31 40
35 00	.81915	9.257314	1036.20	.57358	9.758591	35 00

Note.—These Coordinates locate the point A' where the Spiral ar ($n + 1$) produced backward would meet a parallel tangent. They do no apply to the selected curve unless this has the same Degree of curve a the Spiral arc. (See Table XXXIX.)

CHORD, 10 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
3	18.334	11.667	30.000	.07	15.00
4	25.001	15.001	39.999	.15	20.00
5	31.670	18.337	49.996	.25	25.00
6	38.339	21.674	59.991	.41	29.99
7	45.017	25.016	69.980	.61	34.99
8	51.700	28.363	79.962	.87	39.98
9	58.390	31.719	89.933	1.20	44.96
10	65.094	35.086	99.889	1.60	49.94
11	71.816	38.469	109.824	2.08	54.91
12	78.560	41.873	119.731	2.64	59.87
13	85.333	45.304	129.602	3.30	64.81
14	92.144	48.768	139.429	4.06	69.73
15	99.001	52.276	149.200	4.92	74.63
16	105.916	55.835	158.903	5.90	79.50
17	112.902	59.459	168.524	6.99	84.34
18	119.972	63.161	178.048	8.21	89.13
19	127.144	66.956	187.457	9.56	93.88
20	134.439	70.863	196.731	11.04	98.58

CHORD, 11 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
3	20.17	12.83	33.00	.08	16.50
4	27.50	16.50	44.00	.16	22.00
5	34.84	20.17	55.00	.28	27.50
6	42.17	23.84	65.99	.45	32.99
7	49.52	27.52	76.98	.67	38.49
8	56.87	31.20	87.96	.96	43.98
9	64.23	34.89	98.93	1.32	49.46
10	71.60	38.59	109.88	1.76	54.94
11	79.00	42.32	120.81	2.28	60.40
12	86.42	46.06	131.70	2.91	65.86
13	93.87	49.83	142.56	3.63	71.29
14	101.36	53.65	153.37	4.46	76.71
15	108.90	57.50	164.12	5.41	82.09
16	116.51	61.42	174.79	6.49	87.45
17	124.19	65.41	185.38	7.69	92.77
[illegible]	131.97	69.48	195.85	9.03	98.05
[illegible]	139.86	73.65	206.20	10.51	103.27
[illegible]	147.88	77.95	216.40	12.14	108.43

CHORD, 12 FEET

Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
22.00	14.00	36.00	.09	18.00
30.00	18.00	48.00	.17	24.00
38.00	22.00	60.00	.31	30.00
46.01	26.01	71.99	.49	35.99
54.02	30.02	83.98	.73	41.99
62.04	34.04	95.96	1.05	47.98
70.07	38.06	107.92	1.44	53.96
78.11	42.10	119.87	1.92	59.93
86.18	46.16	131.79	2.49	65.90
94.27	50.25	143.68	3.17	71.84
102.40	54.36	155.52	3.96	77.77
110.57	58.52	167.31	4.87	83.68
118.80	62.73	179.04	5.90	89.56
127.10	67.00	190.68	7.08	95.40
135.48	71.35	202.23	8.39	101.21
143.97	75.79	213.66	9.85	106.96
152.57	80.35	224.95	11.47	112.66
161.33	85.04	236.08	13.24	118.29

CHORD, 13 FEET

Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
23.83	15.17	39.00	.09	19.50
32.50	19.50	52.00	.19	26.00
41.17	23.84	64.99	.33	32.50
49.84	28.18	77.99	.53	38.99
58.52	32.52	90.97	.79	45.49
67.21	36.87	103.95	1.13	51.97
75.91	41.23	116.91	1.56	58.45
84.62	45.61	129.86	2.08	64.93
93.36	50.01	142.77	2.70	71.39
102.13	54.43	155.65	3.43	77.83
110.93	58.89	168.48	4.29	84.25
119.79	63.40	181.26	5.27	90.65
128.70	67.96	193.96	6.40	97.02
137.69	72.59	206.57	7.67	103.35
146.77	77.30	219.08	9.09	109.64
155.96	82.11	231.46	10.67	115.87
165.29	87.04	243.69	12.42	122.05
174.77	92.12	255.75	14.35	[illegible]

CHORD, 14 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	25.67	16.33	42.00	.10	21.00
4	35.00	21.00	56.00	.20	28.00
5	44.34	25.67	69.99	.36	35.00
6	53.67	30.34	83.99	.57	41.99
7	63.02	35.02	97.97	.86	48.98
8	72.38	39.71	111.95	1.22	55.97
9	81.75	44.41	125.91	1.68	62.95
10	91.13	49.12	139.84	2.24	69.92
11	100.54	53.86	153.75	2.91	76.88
12	109.98	58.62	167.62	3.70	83.82
13	119.47	63.43	181.44	4.62	90.74
14	129.00	68.28	195.20	5.68	97.63
15	138.60	73.19	208.88	6.89	104.48
16	148.28	78.17	222.46	8.26	111.30
17	158.06	83.24	235.93	9.79	118.07
18	167.96	88.43	249.27	11.49	124.79
19	178.00	93.74	262.44	13.38	131.44
20	188.21	99.21	275.42	15.45	138.01

CHORD, 15 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	27.50	17.50	45.00	.11	22.50
4	37.50	22.50	60.00	.22	30.00
5	47.51	27.51	74.99	.38	37.50
6	57.51	32.51	89.99	.61	44.99
7	67.53	37.52	104.97	.92	52.48
8	77.55	42.54	119.94	1.31	59.97
9	87.59	47.58	134.90	1.80	67.45
10	97.64	52.63	149.83	2.40	74.91
11	107.72	57.70	164.74	3.11	82.37
12	117.84	62.81	179.60	3.96	89.80
13	128.00	67.96	194.40	4.95	97.22
14	138.22	73.15	209.14	6.09	104.30
15	148.50	78.41	223.80	7.38	111.95
[illegible]	158.87	83.75	238.35	8.85	119.25
[illegible]	169.35	89.19	252.79	10.49	126.51
[illegible]	179.96	94.74	267.07	12.31	133.70
[illegible]	190.72	100.43	281.19	14.33	140.82
[illegible]	201.66	106.29	295.10	16.55	147.88

CHORD, 16 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	29.33	18.67	48.00	.12	24.00
4	40.00	24.00	64.00	.23	32.00
5	50.67	29.34	79.99	.41	40.00
6	61.34	34.68	95.98	.65	47.99
7	72.03	40.03	111.97	.98	55.98
8	82.72	45.38	127.94	1.40	63.97
9	93.42	50.75	143.89	1.92	71.94
10	104.15	56.14	159.82	2.56	79.91
11	114.90	61.55	175.72	3.32	87.86
12	125.70	67.00	191.57	4.23	95.79
13	136.53	72.49	207.36	5.28	103.70
14	147.43	78.03	223.09	6.49	111.57
15	158.40	83.64	238.72	7.87	119.41
16	169.47	89.34	254.24	9.43	127.20
17	180.64	95.14	269.64	11.19	134.94
18	191.96	101.06	284.88	13.18	142.61
19	203.43	107.13	299.93	15.29	149.21
20	215.10	113.38	314.77	17.65	157.72

CHORD, 17 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	31.17	19.83	51.00	.12	25.50
4	42.50	25.50	68.00	.25	34.00
5	53.84	31.17	84.99	.43	42.50
6	65.18	36.85	101.98	.69	50.99
7	76.53	42.53	118.97	1.04	59.48
8	87.89	48.22	135.94	1.48	67.96
9	99.26	53.92	152.89	2.04	76.44
10	110.66	59.65	169.81	2.72	84.90
11	122.09	65.40	186.70	3.53	93.35
12	133.55	71.18	203.54	4.49	101.78
13	145.07	77.02	220.32	5.61	110.18
14	156.64	82.91	237.03	6.90	118.55
15	168.30	88.87	253.64	8.37	126.87
16	180.06	94.92	270.13	10.02	135.15
17	191.93	101.08	286.49	11.88	143.87
18	203.95	107.37	302.68	13.98	151.53
19	216.15	113.83	318.68	16.24	158.60
20	228.55	120.47	334.44	18.76	167.58

CHORD 18 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
3	33.00	21.00	54.00	.13	27.00
4	45.00	27.00	72.00	.26	36.00
5	57.01	33.01	89.99	.46	45.00
6	69.01	39.01	107.98	.73	53.99
7	81.03	45.03	125.96	1.10	62.98
8	93.06	51.05	143.93	1.57	71.96
9	105.10	57.09	161.88	2.16	80.94
10	117.17	63.16	179.80	2.88	89.90
11	129.27	69.24	197.68	3.74	98.84
12	141.41	75.37	215.51	4.75	107.76
13	153.60	81.55	233.28	5.94	116.66
14	165.86	87.78	250.97	7.30	125.52
15	178.20	94.10	268.56	8.86	134.34
16	190.65	100.50	286.03	10.61	143.10
17	203.22	107.03	303.34	12.58	151.81
18	215.95	113.69	320.49	14.78	160.44
19	228.86	120.52	337.42	17.20	167.99
20	241.99	127.55	354.12	19.86	177.44

CHORD, 19 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
3	34.83	22.17	57.00	.14	28.50
4	47.50	28.50	76.00	.28	38.00
5	60.17	34.84	94.99	.48	47.49
6	72.84	41.18	113.98	.77	56.99
7	85.53	47.53	132.96	1.16	66.48
8	98.23	53.89	151.93	1.66	75.96
9	110.94	60.27	170.87	2.28	85.43
10	123.68	66.66	189.79	3.04	94.89
11	136.45	73.09	208.66	3.95	104.33
12	149.26	79.56	227.49	5.02	113.75
13	162.13	86.08	246.24	6.27	123.14
14	175.07	92.66	264.91	7.71	132.49
15	188.10	99.32	283.48	9.35	141.80
16	201.24	106.09	301.92	11.20	151.05
[illegible]	[illegible]4.51	112.97	320.20	13.28	160.24
[illegible]	[illegible]7.95	120.01	338.29	15.60	169.35
[illegible]	[illegible]1.57	127.22	356.17	18.16	177.38
[illegible]	[illegible]5.43	134.64	373.79	20.97	187.80

CHORD, 20 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
3	36.67	23.33	60.00	.15	30.00
4	50.00	30.00	80.00	.29	40.00
5	63.34	36.67	99.99	.51	49.99
6	76.68	43.35	119.98	.81	59.99
7	90.04	50.03	139.96	1.22	69.98
8	103.40	56.73	159.92	1.74	79.96
9	116.78	63.44	179.87	2.40	89.93
10	130.19	70.17	199.78	3.20	99.89
11	143.63	76.94	219.65	4.15	109.83
12	157.12	83.75	239.46	5.28	119.74
13	170.67	90.61	259.20	6.60	129.62
14	184.29	97.54	278.86	8.11	139.47
15	198.00	104.55	298.40	9.84	149.26
16	211.83	111.67	317.81	11.79	159.00
17	225.80	118.92	337.04	13.98	168.68
18	239.94	126.32	356.10	16.42	178.27
19	254.29	133.91	374.91	19.11	186.76
20	268.88	141.73	393.46	22.07	197.15

CHORD, 21 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
3	38.50	24.50	63.00	.15	31.50
4	52.50	31.50	84.00	.31	42.00
5	66.51	38.51	104.99	.53	52.49
6	80.51	45.52	125.98	.86	62.99
7	94.54	52.53	146.96	1.28	73.48
8	108.57	59.56	167.92	1.83	83.96
9	122.62	66.61	188.86	2.52	94.43
10	136.70	73.68	209.77	3.36	104.88
11	150.81	80.79	230.63	4.36	115.32
12	164.98	87.93	251.43	5.55	125.73
13	179.20	95.14	272.16	6.93	136.10
14	193.50	102.41	292.80	8.52	146.44
15	207.90	109.78	313.32	10.33	156.73
16	222.42	117.25	333.70	12.38	166.95
17	237.09	124.86	353.90	14.68	177.11
18	251.94	132.64	373.90	17.24	187.18
19	267.00	140.61	393.66	20.07	196.15
20	282.32	148.81	413.13	23.18	207.01

CHORD, 22 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL	Offset *p*.	Dist. *q*.
3	40.33	25.67	66.00	.16	33.00
4	55.00	33.00	88.00	.32	44.00
5	69.67	40.34	109.99	.56	54.99
6	84.35	47.68	131.98	.90	65.99
7	99.04	55.04	153.96	1.34	76.97
8	113.74	62.40	175.92	1.92	87.95
9	128.46	69.78	197.85	2.64	98.92
10	143.21	77.19	219.76	3.52	109.88
11	157.99	84.63	241.61	4.57	120.81
12	172.83	92.12	263.41	5.81	131.71
13	187.73	99.67	285.12	7.26	142.58
14	202.72	107.29	306.74	8.93	153.41
15	217.80	115.01	328.24	10.83	164.19
16	233.02	122.84	349.59	12.97	174.90
17	248.38	130.81	370.75	15.38	185.54
18	263.94	138.95	391.71	18.06	196.09
19	279.72	147.30	402.40	21.02	205.54

CHORD, 23 FEET

3	42.17	26.83	69.00	.17	34.50
4	57.50	34.50	92.00	.33	46.00
5	72.84	42.17	114.99	.59	57.49
6	88.18	49.85	137.98	.94	68.99
7	103.54	57.54	160.95	1.40	80.47
8	118.91	65.24	183.91	2.01	91.95
9	134.30	72.95	206.85	2.76	103.42
10	149.72	80.70	229.74	3.68	114.87
11	165.18	88.48	252.59	4.78	126.30
12	180.69	96.31	275.38	6.08	137.70
13	196.27	104.20	298.08	7.59	149.06
14	211.93	112.17	320.69	9.33	160.39
15	227.70	120.23	343.16	11.32	171.65
16	243.61	128.42	365.48	13.56	182.85
17	259.67	136.76	387.61	16.08	193.98
18	275.94	145.27	409.50	18.88	205.01

CHORD, 24 FEET

3	44.00	28.00	72.00	.17	36.00
4	60.00	36.00	96.00	.35	48.00
5	76.01	44.01	119.99	.61	59.99
6	92.01	52.02	143.98	.98	71.99
7	108.04	60.04	167.95	1.47	83.97
8	124.08	68.07	191.91	2.09	95.95
9	140.14	76.13	215.84	2.88	107.92
10	156.23	84.21	239.73	3.84	119.86
11	172.36	92.33	263.58	4.98	131.79
12	188.54	100.50	287.35	6.34	143.69
13	204.80	108.73	311.04	7.92	155.55
14	221.15	117.04	334.63	9.74	167.36
15	237.60	125.46	358.08	11.81	179.12
16	254.20	134.01	381.37	14.15	190.80
17	270.96	142.70	404.46	16.78	202.41

CHORD, 25 FEET

Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
45.83	29.17	75.00	.18	37.50
62.50	37.50	100.00	.36	50.00
79.18	45.84	124.99	.64	62.49
95.85	54.19	149.98	1.02	74.99
112.54	62.54	174.95	1.53	87.47
129.25	70.91	199.91	2.18	99.95
145.98	79.30	224.83	3.00	112.41
162.74	87.72	249.72	4.00	124.86
179.54	96.17	274.56	5.19	137.28
196.40	104.68	299.33	6.60	149.67
213.33	113.26	324.00	8.25	162.03
230.36	121.92	348.57	10.14	174.38
247.50	130.69	373.00	12.30	186.58
264.79	139.59	397.26	14.74	198.75
282.25	148.65	421.31	17.48	210.85

CHORD, 26 FEET

47.67	30.33	78.00	.19	39.00
65.00	39.00	104.00	.38	52.00
82.34	47.68	129.99	.66	64.99
99.68	56.35	155.98	1.06	77.98
117.05	65.04	181.95	1.59	90.97
134.42	73.74	207.90	2.27	103.95
151.82	82.47	233.83	3.12	116.91
169.25	91.22	259.71	4.16	129.85
186.72	100.02	285.54	5.40	142.77
204.25	108.87	311.30	6.87	155.66
221.87	117.79	336.97	8.58	168.51
239.57	126.80	362.51	10.55	181.31
257.40	135.92	387.92	12.79	194.04
275.38	145.17	413.15	15.33	206.70

CHORD, 27 FEET

49.50	31.50	81.00	.20	40.50
67.50	40.50	108.00	.39	54.00
85.51	49.51	134.99	.69	67.49
103.52	58.52	161.97	1.10	80.98
121.55	67.54	188.95	1.65	94.47
139.59	76.58	215.90	2.36	107.94
157.65	85.64	242.82	3.24	121.40
175.75	94.73	269.70	4.31	134.85
193.90	103.87	296.52	5.61	148.26
212.11	113.06	323.27	7.13	161.65
230.40	122.32	349.93	8.91	174.98
248.79	131.67	376.46	10.95	188.28
267.30	141.14	402.84	13.29	201.51

CHORD, 28 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	51.33	32.67	84.00	.20	42.00
4	70.00	42.00	112.00	.41	56.00
5	88.68	51.34	139.99	.71	69.99
6	107.35	60.69	167.97	1.14	83.98
7	126.05	70.04	195.94	1.71	97.97
8	144.76	79.42	223.89	2.44	111.94
9	163.49	88.81	251.81	3.36	125.90
10	182.26	98.24	279.69	4.47	139.84
11	201.08	107.71	307.51	5.81	153.76
12	219.97	117.24	335.25	7.40	167.63
13	238.93	126.85	362.89	9.24	181.47
14	258.00	136.55	390.40	11.36	195.25
15	277.20	146.37	417.76	13.78	208.97

CHORD, 29 FEET

3	53.17	33.83	87.00	.21	43.50
4	72.50	43.50	116.00	.42	58.00
5	91.84	53.18	144.99	.74	72.49
6	111.18	62.86	173.97	1.18	86.98
7	130.55	72.55	202.94	1.77	101.47
8	149.93	82.25	231.89	2.53	115.94
9	169.33	91.98	260.81	3.48	130.40
10	188.77	101.75	289.68	4.63	144.84
11	208.26	111.56	318.49	6.02	159.25
12	227.82	121.43	347.22	7.66	173.62
13	247.47	131.38	375.85	9.57	187.95
14	267.22	141.43	404.34	11.77	202.23

CHORD, 30 FEET

3	55.00	35.00	90.00	.22	45.00
4	75.00	45.00	120.00	.44	60.00
5	95.01	55.01	149.99	.76	74.99
6	115.02	65.02	179.97	1.22	89.98
7	135.05	75.05	209.94	1.83	104.97
8	155.10	85.09	239.89	2.62	119.94
9	175.17	95.16	269.80	3.60	134.89
10	195.28	105.26	299.67	4.79	149.83
[illegible]	215.45	115.41	329.47	6.23	164.74
[illegible]	235.68	125.62	359.19	7.92	179.61
[illegible]	256.00	135.91	388.81	9.90	194.43
[illegible]	276.43	146.31	418.29	12.17	209.20

CHORD, 31 FEET

Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
56.83	36.17	93.00	.23	46.50
77.50	46.50	124.00	.45	62.00
98.18	56.84	154.99	.79	77.49
118.85	67.19	185.97	1.26	92.98
139.55	77.55	216.94	1.89	108.46
160.27	87.93	247.88	2.70	123.94
181.01	98.33	278.79	3.72	139.39
201.79	108.77	309.66	4.95	154.82
222.63	119.25	340.45	6.44	170.23
243.53	129.81	371.16	8.19	185.60
264.53	140.44	401.77	10.23	200.91

CHORD, 32 FEET

58.67	37.33	96.00	.23	48.00
80.00	48.00	128.00	.47	64.00
101.35	58.68	159.99	.81	79.99
122.69	69.36	191.97	1.30	95.98
144.06	80.05	223.94	1.95	111.96
165.44	90.76	255.88	2.79	127.93
186.85	101.50	287.79	3.84	143.89
208.30	112.28	319.64	5.11	159.82
229.81	123.10	351.44	6.65	175.72
251.39	133.99	383.14	8.45	191.58
273.07	144.97	414.73	10.56	207.39

CHORD, 33 FEET

60.50	38.50	99.00	.24	49.50
82.50	49.50	132.00	.48	66.00
104.51	60.51	164.99	.84	82.49
126.52	71.53	197.97	1.34	98.98
148.56	82.55	230.93	2.02	115.46
170.61	93.60	263.88	2.88	131.93
192.69	104.67	296.78	3.96	148.38
214.81	115.78	329.63	5.27	164.81
236.99	126.95	362.42	6.85	181.21
259.25	138.18	395.11	8.72	197.57
281.58	149.50	427.69	10.89	[illegible]

CHORD, 34 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	62.33	39.67	102.00	.25	51.00
4	85.00	51.00	136.00	.49	68.00
5	107.68	62.34	169.99	.87	84.99
6	130.35	73.69	203.97	1.38	101.98
7	153.06	85.05	237.93	2.08	118.96
8	175.78	96.44	271.87	2.97	135.93
9	198.53	107.84	305.77	4.08	152.88
10	221.32	119.29	339.62	5.43	169.81
11	244.17	130.80	373.40	7.06	186.70
12	267.10	142.37	407.08	8.98	203.56

CHORD, 35 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	64.17	40.83	105.00	.25	52.50
4	87.50	52.50	140.00	.51	70.00
5	110.85	64.18	174.99	.89	87.49
6	134.19	75.86	209.97	1.43	104.98
7	157.56	87.56	244.93	2.14	122.46
8	180.95	99.27	279.87	3.05	139.93
9	204.37	111.02	314.77	4.20	157.38
10	227.83	122.80	349.61	5.59	174.80
11	251.35	134.64	384.38	7.27	192.19
12	274.96	146.56	419.06	9.24	209.54

CHORD, 36 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	66.00	42.00	108.00	.26	54.00
4	90.01	54.00	144.00	.52	72.00
5	114.01	66.01	179.99	.92	89.99
6	138.02	78.03	215.96	1.47	107.98
7	162.06	90.06	251.93	2.20	125.96
8	186.12	102.11	287.86	3.14	143.93
[illegible]	210.21	114.19	323.76	4.32	161.87
[illegible]	234.34	126.31	359.60	5.75	179.80
[illegible]	258.54	138.49	395.36	7.48	197.69
[illegible]	282.81	150.74	431.03	9.51	215.52

CHORD, 37 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	67.83	43.17	111.00	.27	55.50
4	92.51	55.50	148.00	.54	74.00
5	117.18	67.85	184.99	.94	92.49
6	141.86	80.20	221.97	1.51	110.98
7	166.56	92.56	258.93	2.26	129.46
8	191.29	104.94	295.86	3.23	147.92
9	216.04	117.36	332.75	4.44	166.37
10	240.85	129.82	369.59	5.91	184.79
11	265.72	142.34	406.35	7.68	203.18

CHORD, 38 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	69.67	44.33	114.00	.28	57.00
4	95.01	57.00	151.99	.55	76.00
5	120.35	69.68	189.98	.97	94.99
6	145.69	82.36	227.96	1.56	113.98
7	171.07	95.06	265.92	2.32	132.96
8	196.46	107.78	303.86	3.31	151.92
9	221.88	120.53	341.75	4.56	170.87
10	247.36	133.33	379.58	6.07	189.78
11	272.90	146.18	417.33	7.89	208.67

CHORD, 39 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	71.50	45.50	117.00	.28	58.50
4	97.51	58.50	155.99	.57	78.00
5	123.51	71.51	194.98	.99	97.49
6	149.52	84.53	233.96	1.59	116.98
7	175.57	97.56	272.92	2.38	136.46
8	201.63	110.62	311.85	3.40	155.92
9	227.72	123.70	350.74	4.68	175.38
10	253.87	136.84	389.57	6.23	194.78
1	280.08	150.03	428.31	8.09	214.[illegible]

CHORD, 40 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	73.33	46.67	120.00	.29	60.00
4	100.01	60.01	159.99	.58	80.00
5	126.68	73.35	199.98	1.02	99.99
6	153.36	86.70	239.96	1.63	119.98
7	180.07	100.06	279.92	2.44	139.95
8	206.80	113.45	319.85	3.49	159.92
9	233.56	126.88	359.73	4.80	179.86
10	260.38	140.34	399.56	6.39	199.77
					219.65

CHORD, 41 FEET

3	75.17	47.83	123.00	.30	61.50
4	102.51	61.51	163.99	.60	82.00
5	129.85	75.18	204.98	1.04	102.49
6	157.19	88.87	245.96	1.67	122.98
7	184.57	102.57	286.92	2.50	143.45
8	211.97	116.29	327.85	3.58	163.91
9	239.40	130.05	368.73	4.92	184.36
10	266.89	143.85	409.54	6.55	204.77

CHORD, 42 FEET

3	77.00	49.00	126.00	.31	63.00
4	105.01	63.01	167.99	.61	84.00
5	133.02	77.01	209.98	1.07	104.99
[illegible]	161.02	91.03	251.96	1.71	125.98
[illegible]	189.07	105.07	293.92	2.56	146.95
[illegible]	217.14	119.13	335.84	3.66	167.91
[illegible]	245.24	133.22	377.72	5.04	188.85
[illegible]	273.40	147.36	419.58	6.71	209.76

CHORD, 43 FEET

Tangent SE.	Tangent LE.	L. Chord SL.	Offset p.	Dist. q.
78.83	50.17	129.00	.31	64.50
107.51	64.51	171.99	.63	86.00
136.18	78.85	214.98	1.09	107.49
164.86	93.20	257.96	1.75	128.97
193.58	107.57	300.91	2.63	150.45
222.31	121.96	343.84	3.75	171.91
251.08	136.39	386.71	5.16	193.35
279.91	150.87	429.52	6.87	214.76

CHORD, 44 FEET

80.67	51.33	132.00	.32	66.00
110.01	66.01	175.99	.64	88.00
139.35	80.68	219.98	1.12	109.99
168.69	95.37	263.96	1.79	131.97
198.08	110.07	307.01	2.69	153.95
227.48	124.80	351.83	3.84	175.91
256.92	139.56	395.71	5.28	197.84
286.42	154.38	439.51	7.03	219.75

CHORD, 45 FEET

82.50	52.50	135.00	.33	67.50
112.51	67.51	179.99	.65	90.00
142.52	82.52	224.98	1.15	112.49
172.53	97.54	269.96	1.83	134.97
202.58	112.57	314.91	2.75	157.45
232.65	127.63	359.83	3.93	179.91
262.76	142.73	404.70	5.40	202.34
292.92	157.89	449.50	7.19	224.74

CHORD, 46 FEET

84.33	53.67	138.00	.33	69.00
115.01	69.01	183.99	.67	91.99
145.68	84.35	229.98	1.17	114.99
176.36	99.70	275.96	1.87	137.97
207.08	115.07	321.91	2.81	160.95
237.82	130.47	367.83	4.01	183.90
268.60	145.91	413.69	5.52	206.84
299.43	161.40	459.49	7.35	229.74

TABLE XXXVIII.—SPIRAL TANGENTS, LONG CHORD AND COORDINATES, *p* AND *q*

CHORD, 47 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	86.17	54.84	141.00	.34	70.50
4	117.51	70.51	187.99	.68	93.99
5	148.85	86.18	234.98	1.20	117.49
6	180.19	101.87	281.96	1.91	140.97
7	211.58	117.58	328.91	2.87	164.45
8	242.99	133.31	375.82	4.10	187.90
9	274.43	149.08	422.69	5.64	211.33
10	305.98	164.90	469.48	7.51	234.73

CHORD, 48 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	88.00	56.00	144.00	.35	72.00
4	120.01	72.01	191.99	.70	95.99
5	152.02	88.02	239.98	1.22	119.99
6	184.03	104.04	287.95	1.95	143.97
7	216.08	120.08	335.90	2.93	167.94
8	248.16	136.14	383.82	4.19	191.90
9	280.27	152.25	431.68	5.76	215.83

CHORD, 49 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	89.83	57.17	147.00	.36	73.50
4	122.51	73.51	195.99	.71	97.99
5	155.18	89.85	244.98	1.25	122.49
6	187.86	106.20	293.95	2.00	146.97
7	220.58	122.58	342.90	2.99	171.44
8	253.33	138.98	391.82	4.27	195.90
9	286.11	155.42	440.68	5.88	220.38

CHORD, 50 FEET

n	Tangent SE.	Tangent LE.	L. Chord SL.	Offset *p*.	Dist. *q*.
3	91.67	58.34	150.00	.36	75.00
4	125.01	75.01	199.99	.73	99.99
5	158.35	91.68	249.98	1.27	124.99
6	191.70	108.37	299.95	2.04	149.97
7	225.09	125.08	349.90	3.05	174.94
8	258.50	141.82	399.81	4.36	199.90
9	291.95	158.59	449.67	6.00	224.82

TABLE XXXIX.—SELECTED CURVES WITH PROPER SPIRALS

D′	n	c	s	R′ vers s	R′ sin s	q	p
1° 40′	3	40	1° 00′	0.524	59.999	59.987	0.291
1 40	4	50	1 40	1.454	99.989	99.992	0.727
2	3	33	1 00	0.436	50.000	48.997	0.236
2	4	42	1 40	1.212	83.326	84.658	0.620
2	5	50	2 30	2.727	124.967	124.981	1.272
2 30	3	27	1 00	0.349	40.001	40.996	0.201
2 30	4	33	1 40	0.970	66.663	65.325	0.470
2 30	5	40	2 30	2.181	99.976	99.983	1.018
2 30	6	47	3 30	4.275	139.924	141.963	1.944
3	3	22	1 00	0.291	33.835	32.663	0.157
3	4	28	1 40	0.808	55.554	56.436	0.414
3	5	33	2 30	1.818	83.317	81.649	0.821
3	6	38	3 30	3.563	116.607	111.302	1.465
3	7	44	4 40	6.332	155.401	152.381	2.623
3	8	50	6 00	10.464	199.658	199.878	4.360
3 20	3	20	1 00	0.262	30.003	29.995	0.145
3 20	4	25	1 40	0.727	50.000	49.991	0.364
3 20	5	30	2 30	1.636	74.987	74.982	0.764
3 20	6	35	3 30	3.207	104.950	104.966	1.424
3 20	7	40	4 40	5.699	139.865	139.937	2.442
3 20	8	45	6 00	9.417	179.697	179.886	3.924
3 20	9	50	7 30	14.707	224.390	224.800	5.994
4	4	21	1 40	0.606	41.669	42.323	0.310
4	5	25	2 30	1.364	62.493	62.481	0.636
4	6	29	3 30	2.672	87.463	86.467	1.165
4	7	33	4 40	4.750	116.561	114.276	1.966
4	8	37	6 00	7.848	149.757	145.900	3.122
4	9	41	7 30	12.257	187.003	181.333	4.718
4	10	46	9 10	18.297	228.237	230.532	7.415
4 10	4	20	1 40	0.582	40.003	39.990	0.291
4 10	5	24	2 30	1.309	59.994	59.981	0.611
4 10	6	28	3 30	2.565	83.966	83.967	1.140
4 10	7	32	4 40	4.560	111.901	111.941	1.953
4 10	8	36	6 00	7.535	143.769	143.897	3.138
4 10	9	40	7 30	11.867	179.526	179.826	4.694
4 10	10	44	9 10	17.565	219.111	219.711	7.029
5	5	20	2 30	1.091	50.000	49.979	0.509
5	6	23	3 30	2.138	69.979	67.966	0.905
5	7	27	4 40	3.800	93.260	95.606	1.695
5	8	30	6 00	6.279	119.819	119.903	2.615
5	9	33	7 30	9.807	149.619	146.846	3.855
5	10	37	9 10	14.639	182.610	186.400	6.042
5	11	40	11 00	21.060	218.720	219.592	8.301
5 20	5	19	2 30	1.023	46.877	48.103	0.497
5 20	6	22	3 30	2.004	65.608	66.339	0.907
5 20	7	25	4 40	3.563	87.435	87.441	1.525
5 20	8	28	6 00	5.887	112.335	111.405	2.414
5 20	9	31	7 30	9.408	140.275	138.223	3.426
5 20	10	34	9 10	13.725	171.204	167.886	5.279
5 20	11	37	11 00	19.745	205.060	200.378	7.414
5 50	5	17	2 30	0.935	42.862	42.120	0.425
5 50	6	20	3 30	1.833	59.988	59.964	0.813
5 50	7	23	4 40	3.258	79.946	80.940	1.423

D′	n	c	s	R′ vers s	R′ sin s	q	p
5° 50′	8	26	6° 00′	5.383	102.714	105.045	2.325
5 50	9	29	7 30	8.407	128.260	132.270	3.599
5 50	10	31	9 10	12.549	156.541	152.629	4.778
5 50	11	34	11 00	18.054	187.496	185.069	6.903
6	5	17	2 30	0.909	41.673	43.309	0.451
6	6	19	3 30	1.782	58.324	55.630	0.732
6	7	22	4 40	3.167	77.727	76.164	1.311
6	8	25	6 00	5.234	99.863	99.905	2.178
6	9	28	7 30	8.173	124.700	126.846	3.419
6	10	31	9 10	12.201	152.196	156.974	5.126
6	11	33	11 00	17.553	182.293	179.314	6.670
6 40	6	18	3 30	1.604	52.497	55.460	0.778
6 40	7	20	4 40	2.851	69.962	69.939	1.220
6 40	8	23	6 00	4.711	89.886	93.901	2.108
6 40	9	25	7 30	7.357	112.242	112.353	2.993
6 40	10	28	9 10	10.982	136.991	142.260	4.668
6 40	11	30	11 00	15.799	164.081	164.653	6.222
6 40	12	33	13 00	22.040	193.440	200.446	9.044
7	6	17	3 30	1.528	50.000	51.959	0.721
7	7	19	4 40	2.715	66.634	66.272	1.152
7	8	21	6 00	4.487	85.611	82.194	1.739
7	9	24	7 30	7.007	106.904	108.707	2.929
7	10	26	9 10	10.460	130.476	128.828	4.073
7	11	29	11 00	15.048	156.278	161.498	6.239
7	12	31	13 00	21.480	184.240	185.774	7.720
7 30	7	18	4 40	2.534	62.198	63.713	1.129
7 30	8	20	6 00	4.188	79.911	79.904	1.742
7 30	9	22	7 30	6.540	99.786	97.857	2.568
7 30	10	24	9 10	9.763	121.788	117.570	3.652
7 30	11	27	11 00	14.046	145.871	149.989	5.773
7 30	12	29	13 00	19.594	171.976	174.166	7.722
7 30	13	31	15 10	26.628	200.011	200.071	10.115
8	7	17	4 40	2.376	58.316	60.600	1.084
8	8	19	6 00	3.927	74.924	76.900	1.706
8	9	21	7 30	6.132	93.558	95.102	2.562
8	10	23	9 10	9.154	114.188	115.196	3.702
8	11	25	11 00	13.169	136.768	137.177	5.182
8	12	27	13 00	18.371	161.240	161.030	7.061
8	13	29	15 10	24.966	187.529	186.742	9.407
8 20	7	16	4 40	2.281	55.988	55.933	0.975
8 20	8	18	6 00	3.770	71.932	71.901	1.567
8 20	9	20	7 30	5.887	89.822	89.854	2.393
8 20	10	22	9 10	8.788	109.628	109.783	3 509
8 20	11	24	11 00	12.643	131.306	131.681	4.974
8 20	12	26	13 00	17.637	154.801	155.533	6.853
8 20	13	28	15 10	23.969	180.041	181.324	9.219
9	7	15	4 40	2.113	51.848	53.078	0.940
9	8	17	6 00	3.491	66.613	69.229	1.549
9	9	19	7 30	5.452	83.181	87.511	2.414
9	10	20	9 10	8.139	101.523	97.942	3.040
[illegible]	11	22	11 00	11.709	121.598	119.473	4.440
[illegible]	12	24	13 00	16.333	143.356	143.107	6.274
[illegible]	13	26	15 10	22.197	166.729	168.824	8.620
[illegible]	14	28	17 30	29.495	191.632	196.603	11.567

	n	*c*	*s*	*R′* vers *s*	*R′* sin *s*	*q*	*p*
20′	7	14	4° 40′	2.037	50.000	47.931	0.812
20	8	16	6 00	3.367	64.240	63.612	1.377
20	9	18	7 30	5.258	80.217	81.491	2.194
20	10	20	9 10	7.849	97.904	101.561	3.330
20	11	21	11 00	11.291	117.264	112.850	4.124
20	12	23	13 00	15.751	138.246	136.281	5.914
20	13	25	15 10	21.406	160.787	161.860	8.226
20	14	27	17 30	28.444	184.803	189.566	11.151
	8	15	6 00	3.135	59.966	59.895	1.312
	9	17	7 30	4.908	74.881	77.844	2.130
	10	18	9 10	7.326	91.392	88.126	2.735
	11	20	11 00	10.540	109.465	109.691	4.141
	12	22	13 00	14.704	129.051	133.540	6.019
	13	23	15 10	19.982	150.092	146.743	7.279
	14	25	17 30	26.552	172.511	174.127	10.110
	15	27	20 00	34.597	196.212	203.724	13.677
40	8	14	6 00	2.947	56.228	55.642	1.204
40	9	16	7 30	4.603	70.213	73.528	2.021
40	10	17	9 10	6.870	85.695	83.850	2.632
40	11	19	11 00	9.883	102.639	105.559	4.064
40	12	20	13 00	13.787	121.007	117.712	5.052
40	13	22	15 10	18.737	140.736	143.193	7.339
40	14	23	17 30	24.897	161.757	157.150	8.832
40	15	25	20 00	32.441	183.981	186.330	12.257
20	8	13	6 00	2.774	52.931	50.948	1.080
20	9	15	7 30	4.332	66.095	68.662	1.878
20	10	16	9 10	6.467	80.669	78.903	2.476
20	11	18	11 00	9.303	96.621	100.619	3.909
20	12	19	13 00	12.978	113.910	112.873	4.919
20	13	21	15 10	17.638	132.482	138.541	7.253
20	14	22	17 30	23.437	152.270	152.772	8.826
20	15	24	20 00	30.538	179.191	176.308	12.372
20	16	25	22 40	39.111	195.142	198.456	14.682
	9	14	7 30	4.092	62.436	63.337	1.704
	10	15	9 10	6.251	76.202	73.397	2.133
	11	17	11 00	8.788	91.271	95.011	3.690
	12	18	13 00	12.263	107.603	107.244	4.695
	13	19	15 10	16.661	125.147	120.065	5.859
	14	21	17 30	22.139	143.839	147.337	8.657
	15	22	20 00	28.847	163.602	162.272	10.488
	16	24	22 40	36.946	184.337	193.517	14.695
30	8	12	6 00	2.516	48.007	47.882	1.042
30	9	13	7 30	3.930	59.948	56.841	1.453
30	10	15	9 10	5.865	73.166	76.433	2.519
30	11	16	11 00	8.438	87.634	87.691	3.306
30	12	17	13 00	11.771	103.315	99.596	4.242
30	13	19	15 10	15.997	120.160	125.052	6.525
30	14	20	17 30	21.257	138.107	139.203	8.073
30	15	21	20 00	27.698	157.082	153.980	9.849
30	16	23	22 40	35.473	176.991	185.119	14.017
30	17	24	25 30	44.740	197.723	202.042	16.695
20	7	10	4 40	1.427	35.040	34.911	0.608
20	8	11	6 00	2.359	45.019	42.879	0.902
20	9	12	7 30	3.685	56.216	51.590	1.283
20	10	14	9 10	5.500	68.612	71.013	2.325
20	11	15	11 00	7.913	82.179	82.188	3.09

D′	*n*	*c*	*s*	*R′* vers *s*	*R′* sin *s*	*q*	*p*
13° 20′	12	16	13° 00′	11.039	96.884	94.091	4.032
13 20	13	17	15 10	15.001	112.680	106.720	5.149
13 20	14	18	17 30	19.934	129.511	120.068	6.463
13 20	15	20	20 00	25.974	146.968	149.281	9.785
13 20	16	21	22 40	33.266	165.974	164.649	11.920
13 20	17	23	25 30	41.955	185.416	197.692	16.920
14 10	8	11	6 00	2.221	42.384	45.514	1.040
14 10	9	12	7 30	3.469	52.925	54.881	1.499
14 10	10	13	9 10	5.178	64.595	65.057	2.088
14 10	11	14	11 00	7.467	77.368	76.041	2.809
14 10	12	15	13 00	10.392	91.212	87.827	3.737
14 10	13	16	15 10	14.123	106.083	100.411	4.841
14 10	14	18	17 30	18.767	121.928	127.651	7.630
14 10	15	19	20 00	24.453	138.680	142.757	9.518
14 10	16	20	22 40	31.318	156.257	158.622	11.717
14 10	17	21	25 30	39.499	174.561	175.234	14.257
14 10	18	22	28 30	49.136	193.475	192.579	17.167
15	8	10	6 00	2.098	40.041	39.866	0.867
15	9	11	7 30	3.277	50.000	48.822	1.277
15	10	12	9 10	4.892	61.025	58.654	1.815
15	11	13	11 00	7.038	73.092	69.359	2.504
15	12	14	13 00	9.818	86.171	80.932	3.369
15	13	15	15 10	13.343	100.220	93.368	4.436
15	14	17	17 30	17.729	115.190	120.524	7.201
15	15	18	20 00	23.102	131.016	135.608	9.081
15	16	19	22 40	29.587	147.621	151.514	11.296
15	17	20	25 30	37.316	164.913	168.225	13.880
15	18	21	28 30	46.421	182.783	185.723	16.868
16 40	9	10	7 30	2.951	45.030	44.808	1.189
16 40	10	11	9 10	4.406	54.960	54.746	1.742
16 40	11	12	11 00	6.338	65.827	65.666	2.470
16 40	12	13	13 00	8.842	77.606	77.561	3.403
16 40	13	14	15 10	12.016	90.259	90.423	4.578
16 40	14	15	17 30	15.967	103.740	104.243	6.080
16 40	15	16	20 00	20.805	117.994	119.005	7.802
16 40	16	17	22 40	26.646	132.948	134.699	9.933
16 40	17	18	25 30	33.607	148.522	151.302	12.469
16 40	18	19	28 30	41.807	164.615	168.795	15.455
16 40	19	20	31 40	51.362	181.112	187.152	18.939
18 20	10	10	9 10	4.008	50.000	49.732	1.581
18 20	11	11	11 00	5.767	59.887	60.649	2.307
18 20	12	12	13 00	8.044	70.603	72.628	3.259
18 20	13	13	15 10	10.932	82.115	85.661	4.477
18 20	14	14	17 30	14.526	94.380	99.737	6.005
18 20	15	15	20 00	18.928	107.347	114.840	7.891
18 20	17	16	25 30	30.575	135.120	131.390	10.382
18 20	18	17	28 30	38.034	149.760	148.554	13.200
18 20	19	18	31 40	46.729	164.769	166.668	16.542
18 20	20	19	35 00	56.761	180.023	185.702	20.465
20	11	10	11 00	5.290	54.941	54.637	2.050
20	12	11	13 00	7.380	64.772	66.523	2.981
20	13	12	15 10	10.029	75.333	79.538	4.194
20	15	13	20 00	17.365	98.481	94.081	5.878
20	16	14	22 40	22.240	110.962	109.453	7.884
20	17	15	25 30	28.049	123.961	125.892	10.348
20	18	16	28 30	34.893	137.392	143.374	13.328
20	19	17	31 40	42.869	151.161	161.863	16.887
20	20	18	35 00	52.073	165.154	181.322	21.088

D′	*n* ç	*s*	*R′* vers *s*	*R′* sin *s*	*q*	*p*
22° 30′	12 10	13° 00′	6.569	57.653	61.706	2.850
22 30	14 11	17 30	11.862	77.068	75.453	4.269
22 30	15 12	20 00	15.456	87.657	90.092	5.999
22 30	16 13	22 40	19.795	98.767	105.904	8.177
22 30	18 14	28 30	31.058	122.264	123.406	11.135
22 30	19 15	31 40	38.158	134.547	141.651	14.568
22 30	20 16	35 00	46.350	147.003	160.976	18.682
25	14 10	17 30	10.692	69.466	69.189	3.973
25	15 11	20 00	13.932	79.010	83.927	5.735
25	17 12	25 30	22.504	101.769	98.114	8.214
25	18 13	28 30	27.995	110.229	117.894	11.184
25	20 14	35 00	41.778	132.502	136.979	15.125
27 30	15 10	20 00	12.628	71.948	76.177	5.251
27 30	17 11	25 30	20.492	90.563	92.663	7.666
27 30	19 12	31 40	31.319	110.435	110.523	10.862
27 30	20 13	35 00	38.044	120.659	129.574	14.795
30	17 10	25 30	18.819	83.168	83.401	6.779
30	19 11	31 40	28.762	101.418	101.127	9.903
30	20 12	35 00	34.937	110.806	120.178	13.837
32 20	18 10	28 30	21.762	85.687	89.792	8.376
32 20	20 11	35 00	32.476	103.001	108.734	12.234
35	20 10	35 00	30.071	95.372	97.115	10.574

SELECTED SPIRALS FOR A 2° CURVE

Δ	s	$n \times c$	$D_{s(n+1)}$	D'	d	x	h
10°	1° 00′	3 × 32	2° 05′ 00″	2° 03′	41.12	.6516	.040
10	1 40	4 × 39	2 08 13	2 09	61.04	1.702	.187
10	2 30	5 × 43	2 19 33	2 18	73.69	3.439	.354
10	3 30	6 × 45	2 35 34	2 33	78.81	5.954	.590
10	4 40	7 × 44	3 01 50	2 40	70.47	8.955	.897
20°	1 00	3 × 33	2 01 13	2 01	45.28	.6719	.122
20	1 40	4 × 41	2 01 57	2 02	73.85	1.789	.118
20	2 30	5 × 48	2 05 00	2 05	99.99	3.839	.527
20	3 30	6 × 50	2 20 00	2 06	109.52	6.616	.554
30°	1 00	3 × 34	1 57 39	2 01	46.14	.6923	.566
30	1 40	4 × 41	2 01 57	2 01	75.16	1.789	.227
30	2 30	5 × 49	2 02 27	2 02	109.78	3.919	.377
30	3 30	6 × 50	2 20 00	2 02	115.63	6.616	.249
30	3 30	6 × 50	2 20 00	2 03	110.90	6.616	1.013
40°	1 00	3 × 35	1 54 17	2 01	46.90	.7127	1.222
40	1 40	4 × 42	1 59 02	2 01	76.96	1.832	.848
40	2 30	5 × 50	2 00 00	2 01	117.87	3.999	.141

SELECTED SPIRALS FOR A 4° CURVE

10°	1° 00′	3 × 16	4° 10′ 03″	4° 07′	20.22	.3258	.045
10	1 40	4 × 19	4 23 13	4 16	29.12	.8290	.080
10	2 30	5 × 22	4 32 48	4 39	38.75	1.760	.177
10	3 30	6 × 23	5 04 26	5 17	41.37	3.043	.305
20°	1 40	4 × 20	4 10 03	4 04	34.92	.8726	.081
20	2 30	5 × 24	4 10 03	4 09	50.72	1.920	.184
20	3 30	6 × 27	4 19 19	4 17	63.69	3.573	.375
20	4 40	7 × 30	4 26 44	4 31	78.07	6.106	.598
20	6 00	8 × 31	4 50 24	4 46	81.88	9.191	.910
20	7 30	9 × 32	5 12 36	5 16	85.40	13.248	1.310
30°	1 40	4 × 20	4 10 03	4 02	35.57	.8726	.137
30	2 30	5 × 25	4 00 03	4 04	57.39	2.000	.147
30	3 30	6 × 28	4 10 03	4 07	72.37	3.705	.284
30	4 40	7 × 32	4 10 03	4 14	93.09	6.513	.687
30	6 00	8 × 35	4 17 12	4 23	110.31	10.377	1.091
30	7 30	9 × 37	4 30 20	4 34	122.20	15.319	1.526
30	9 10	10 × 38	4 49 33	4 47	126.86	21.240	2.126
40°	2 30	5 × 25	4 00 03	4 02	58.91	2.000	.109
40	3 30	6 × 28	4 10 03	4 04	73.75	3.705	.361
40	4 40	7 × 32	4 10 03	4 08	94.65	6.513	.977
40	6 00	8 × 36	4 10 03	4 12	121.38	10.673	.973
40	7 30	9 × 39	4 16 28	4 17	142.86	16.147	1.100
40	9 10	10 × 41	4 28 21	4 26	154.34	22.917	2.186
60°	2 30	5 × 25	4 00 03	4 01	59.68	2.000	.180
60	3 30	6 × 29	4 01 26	4 02	81.04	3.837	.461
60	4 40	7 × 32	4 10 03	4 03	99.59	6.513	.572
60	6 00	8 × 36	4 10 03	4 05	125.81	10.673	1.074
60	7 30	9 × 40	4 10 03	4 08	154.42	16.561	1.718
80°	2 30	5 × 25	4 00 03	4 01	58.29	2.000	.979
80	3 30	6 × 29	4 01 26	4 01	82.82	3.837	.295
80	4 40	7 × 33	4 02 28	4 02	106.99	6.716	1.000
80	6 00	8 × 37	4 03 17	4 03	135.61	10.970	1.199
80	7 30	9 × 41	4 03 57	4 05	164.79	16.975	2.440

SELECTED SPIRALS FOR AN 8° CURVE

Δ	s	$n \times c$	$D_{s(n+1)}$	D'	d	x	h
0°	2° 30′	5 × 11	9° 06′ 01″	9° 06′	19.95	.8798	.051
0°	2 30	5 × 12	8 20 26	8 16	25.71	.9598	.051
0	3 30	6 × 14	8 20 26	8 34	34.86	1.852	.117
0	4 40	7 × 15	8 53 51	8 54	39.90	3.053	.185
0	6 00	8 × 16	9 23 07	9 24	45.52	4.744	.221
0°	2 30	5 × 12	8 20 26	8 07	26.50	.9598	.049
0	3 30	6 × 14	8 20 26	8 14	36.16	1.852	.142
0	4 40	7 × 16	8 20 26	8 26	47.01	3.256	.260
0	6 00	8 × 17	8 49 55	8 36	53.13	5.040	.325
0	7 30	9 × 18	9 16 08	8 46	60.05	7.452	.287
0	9 10	10 × 19	9 39 36	9 14	65.70	10.620	.590
0°	2 30	5 × 12	8 20 26	8 04	26.93	.9598	.079
0	3 30	6 × 14	8 20 26	8 08	36.85	1.852	.181
0	4 40	7 × 16	8 20 26	8 14	48.25	3.256	.293
0	6 00	8 × 18	8 20 26	8 22	61.35	5.337	.330
0	7 30	9 × 19	8 46 49	8 30	68.07	7.866	.472
0	9 10	10 × 20	9 10 34	8 40	75.01	11.179	.629
0	11 00	11 × 21	9 32 03	8 54	82.13	15.415	.840
0	13 00	12 × 22	9 51 36	9 14	89.81	20.723	1.024
0°	2 30	5 × 12	8 20 26	8 02	27.30	.9598	.136
0	3 30	6 × 14	8 20 26	8 03	38.22	1.852	.083
0	4 40	7 × 16	8 20 26	8 06	49.75	3.256	.317
0	6 00	8 × 18	8 20 26	8 10	62.87	5.337	.539
0	7 30	9 × 20	8 20 26	8 16	77.16	8.280	.863
0	9 10	10 × 22	8 20 25	8 24	93.05	12.297	1.139
0	11 00	11 × 23	8 42 13	8 31	101.08	16.883	1.523
0	13 00	12 × 25	8 40 28	8 48	118.19	23.548	2.160
0	15 10	13 × 26	8 58 59	9 02	127.21	30.817	2.613
0	17 30	14 × 27	9 16 07	9 22	136.45	39.595	3.157
0°	4 40	7 × 17	7 50 57	8 04	57.04	3.460	.366
0	6 00	8 × 19	7 54 03	8 06	71.78	5.633	.408
0	7 30	9 × 20	8 20 26	8 08½	79.18	8.280	.860
0	9 10	10 × 22	8 20 25	8 13	95.23	12.297	1.346
0	11 00	11 × 24	8 20 25	8 19	112.67	17.617	1.719
0	13 00	12 × 26	8 20 25	8 28	130.86	24.490	2.738
0	15 10	13 × 27	8 38 59	8 34	140.88	32.002	3.119
0	17 30	14 × 28	8 56 13	8 42	150.55	41.062	3.809

SELECTED SPIRALS FOR A 16° CURVE

Δ	s	$n \times c$	$D_{s(n+1)}$	D'	d	x	h
0°	4° 40′	7 × 10	13° 21′ 48″	18° 00′	33.59	2.035	.388
0°	6 00	8 × 10	15 02 34	17 14	36.14	2.965	.430
0°	7 30	9 × 10	16 43 31	16 32	38.47	4.140	.436
0	9 10	10 × 11	16 43 31	16 48	46.40	6.148	.576
0	11 00	11 × 12	16 43 31	17 14	54.62	8.808	.860
0	13 00	12 × 12	18 07 48	17 22	54.14	11.303	1.093
0	15 10	13 × 13	18 01 18	18 10	62.88	15.409	1.516
0	17 30	14 × 13	19 19 14	18 12	62.85	19.064	1.552
0	20 00	15 × 14	19 06 05	20 00	72.14	25.031	2.182
0°	7 30	9 × 10	16 43 31	16 16	39.74	4.140	.328
0	9 10	10 × 11	16 43 31	16 26	47.49	6.148	.680
0	11 00	11 × 12	16 43 31	16 38	56.19	8.808	.943
0	13 00	12 × 13	16 43 30	16 56	65.24	12.245	1.384
0	15 10	13 × 14	16 43 29	17 22	74.72	16.594	1.973
0	17 30	14 × 14	17 55 44	17 24	75.02	20.531	1.939
0	*20 00*	*15 × 15*	17 50 54	18 06	85.15	26.819	2.657
0	*22 40*	*16 × 15*	18 58 25	18 08	85.18	32.276	2.677
	28 30	*18 × 16*	19 53 20	19 42	95.84	48.221	3.748

The References are to Davies' Legendre, Revised Edition.

No.	REFERENCE.	HYPOTHESES.	CONSEQUENCES.
1	IV., XI.	If a triangle is right angled,	The square on the hypothenuse is equal to the sum of the squares on the other two sides.
2	I., XI., Cor. 1....	If a triangle is equilateral,	It is equiangular.
3	I., XI...........	If a triangle is isosceles,	The angles at the base are equal.
4	I., XI., Cor. 2....	If a straight line from the vertex of an isosceles triangle bisects the base,	It bisects the vertical angle. And is perpendicular to the base.
5	I., XXV., Cor. 6..	If one side of a triangle is produced,	The exterior angle is equal to the sum of the two interior and opposite angles.
6	IV., XX.	If two triangles are mutually equiangular,	They are similar. And their corresponding sides are proportional.
7	I., XXVII........	If the sides of a polygon are produced in the same order,	The sum of the exterior angles equals four right angles.
8	I., XXVI., Cor. 1.	If a figure is a quadrilateral,	The sum of the interior angles equals four right angles.
9	I., XXVIII....... I., XXXI.	If a figure is a parallelogram,	The opposite sides are equal. The opposite angles are equal. It is bisected by its diagonal. And its diagonals bisect each other.
10	III., VII.........	If three points are not in the same straight line,	A circle may be passed through them.
11	III., XVII........	If two arcs are intercepted on the same circle,	They are proportional to the corresponding angles at the centre.
12	V., XIII., Cor. 2..	If two arcs are similar,	They are proportional to their radii.
13	V., XIII.........	If two areas are circles,	They are proportional to the squares on their radii.
14	III., VI..........	If a radius is perpendicular to a chord,	It bisects the chord. And it bisects the arc subtended by the chord.
15	III., IX..........	If a straight line is tangent to a circle,	It meets it in only one point. And it is perpendicular to the radius drawn to that point.
16	III., XIV., Cor... I., XI.	If from a point without a circle tangents are drawn to touch the circle,	There are but two. They are equal. And they mak equal angles with the cho joining the tangent poin

The References are to Davies' Legendre, Revised Edition.

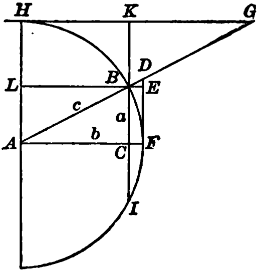
REFERENCE.	HYPOTHESES.	CONSEQUENCES.
III., X...........	If two lines are parallel chords or a tangent and parallel chord,	They intercept equal arcs of a circle.
III., XVIII.......	If an angle at the circumference of a circle is subtended by the same arc as an angle at the centre,	The angle at the circumference is equal to half the angle at the centre.
III., XVIII., Cor.2	If an angle is inscribed in a semicircle,	It is a right angle.
III., XXI.........	If an angle is formed by a tangent and chord,	It is measured by one half of the intercepted arc.
IV., XXVIII., Cor.	If two chords intersect each other in a circle,	The rectangle of the segments of the one, equals the rectangle of the segments of the other.
IV., XXIII., Cor. 2	And if one chord is a diameter, and the other perpendicular to it,	The rectangle of the segments of the diameter is equal to the square on half the other chord. And the half chord is a mean proportional between the segments of the diameter.
IV., XXIX., Cor..	If two secants meet without the circle,	The rectangles of each secant and its external segment are equal.
IV., XXX.........	If a secant and tangent meet,	The rectangle of the secant and its external segment is equal to the square on the tangent. And the tangent is a mean proportional between the secant and its external segment.
IV., XIV.........	If a straight line from the vertex of a triangle bisects its base,	The sum of the squares on the two sides is equal to twice the square of half the base increased by twice the square of the bisecting line.
IV., XII....	If a perpendicular be drawn from the vertex of a triangle to the base,	The square of a side opposite an acute angle is equal to the sum of the squares of the other side and the base, diminished by twice the rectangle of the base and the distance from the vertex of the acute angle to the foot of the perpendicular.

TRIGONOMETRIC FUNCTIONS.

Let A = angle BAC = arc BF, and let the radius $AF = AB = AH = 1$.
$AH = 1$.

We then have

$\sin A = BC$
$\cos A = AC$
$\tan A = DF$
$\cot A = HG$
$\sec A = AD$
$\text{cosec}\ A = AG$
$\text{versin}\ A = CF = BE$
$\text{covers}\ A = BK = HL$
$\text{exsec}\ A = BD$
$\text{coexsec}\ A = BG$
$\text{chord}\ A = BF$
$\text{chord}\ 2A = BI = 2BC$

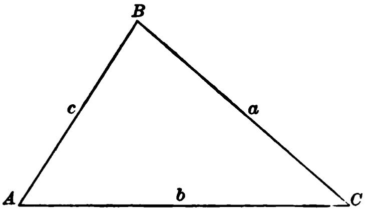


In the right-angled triangle ABC.
Let $AB = c$, $AC = b$, and $BC = a$.
We then have:

1. $\sin A = \dfrac{a}{c} = \cos B$
2. $\cos A = \dfrac{b}{c} = \sin B$
3. $\tan A = \dfrac{a}{b} = \cot B$
4. $\cot A = \dfrac{b}{a} = \tan B$
5. $\sec A = \dfrac{c}{b} = \text{cosec}\ B$
6. $\text{cosec}\ A = \dfrac{c}{a} = \sec B$
7. $\text{vers}\ A = \dfrac{c-b}{c} = \text{covers}\ B$
8. $\text{exsec}\ A = \dfrac{c-b}{b} = \text{coexsec}\ B$
9. $\text{covers}\ A = \dfrac{c-a}{c} = \text{versin}\ B$
10. $\text{coexsec}\ A = \dfrac{c-a}{a} = \text{exsec}\ B$
11. $a = c \sin A = b \tan A$
12. $b = c \cos A = a \cot A$
13. $c = \dfrac{a}{\sin A} = \dfrac{b}{\cos A}$
14. $a = c \cos B = b \cot B$
15. $b = c \sin B = a \tan B$
16. $c = \dfrac{a}{\cos B} = \dfrac{b}{\sin B}$
17. $a = \sqrt{(c+b)(c-b)}$
18. $b = \sqrt{(c+a)(c-a)}$
19. $c = \sqrt{a^2 + b^2}$
20. $C = 90° = A + B$

21. $\text{area} = \dfrac{ab}{2}$

SOLUTION OF OBLIQUE TRIANGLES.



	GIVEN.	SOUGHT.	FORMULAS.
22	A, B, a	C, b, c	$C = 180° - (A + B)$, $b = \frac{a}{\sin A} \cdot \sin B$, $c = \frac{a}{\sin A} \sin (A + B)$
23	A, a, b	B, C, c	$\sin B = \frac{\sin A}{a} \cdot b$, $C = 180° - (A + B)$, $c = \frac{a}{\sin A} \cdot \sin C$.
24	C, a, b	$\frac{1}{2}(A + B)$	$\frac{1}{2}(A + B) = 90° - \frac{1}{2} C$
25		$\frac{1}{2}(A - B)$	$\tan \frac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \frac{1}{2}(A + B)$
26		A, B	$A = \frac{1}{2}(A + B) + \frac{1}{2}(A - B)$, $B = \frac{1}{2}(A + B) - \frac{1}{2}(A - B)$
27		c	$c = (a + b) \frac{\cos \frac{1}{2}(A + B)}{\cos \frac{1}{2}(A - B)} = (a - b) \frac{\sin \frac{1}{2}(A + B)}{\sin \frac{1}{2}(A - B)}$
28		area	$K = \frac{1}{2} a b \sin C$.
29	a, b, c	A	Let $s = \frac{1}{2}(a + b + c)$; $\sin \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{bc}}$
30			$\cos \frac{1}{2} A = \sqrt{\frac{s(s-a)}{bc}}$; $\tan \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$
31			$\sin A = \frac{2\sqrt{s(s-a)(s-b)(s-c)}}{bc}$; $\text{vers } A = \frac{2(s-b)(s-c)}{bc}$
32		area	$K = \sqrt{s(s-a)(s-b)(s-c)}$
33	A, B, C, a	area	$K = \frac{a^2 \sin B \cdot \sin C}{2 \sin A}$

GENERAL FORMULAS.

34 $\sin A = \frac{1}{\operatorname{cosec} A} = \sqrt{1 - \cos^2 A} = \tan A \cos A$

35 $\sin A = 2 \sin \tfrac{1}{2} A \cos \tfrac{1}{2} A = \operatorname{vers} A \cot \tfrac{1}{2} A$

36 $\sin A = \sqrt{\tfrac{1}{2} \operatorname{vers} 2A} = \sqrt{\tfrac{1}{2}(1 - \cos 2A)}$

37 $\cos A = \frac{1}{\sec A} = \sqrt{1 - \sin^2 A} = \cot A \sin A$

38 $\cos A = 1 - \operatorname{vers} A = 2 \cos^2 \tfrac{1}{2} A - 1 = 1 - 2 \sin^2 \tfrac{1}{2} A$

39 $\cos A = \cos^2 \tfrac{1}{2} A - \sin^2 \tfrac{1}{2} A = \sqrt{\tfrac{1}{2} + \tfrac{1}{2} \cos 2A}$

40 $\tan A = \frac{1}{\cot A} = \frac{\sin A}{\cos A} = \sqrt{\sec^2 A - 1}$

41 $\tan A = \sqrt{\frac{1}{\cos^2 A} - 1} = \frac{\sqrt{1 - \cos^2 A}}{\cos A} = \frac{\sin 2A}{1 + \cos 2A}$

42 $\tan A = \frac{1 - \cos 2A}{\sin 2A} = \frac{\operatorname{vers} 2A}{\sin 2A} = \operatorname{exsec} A \cot \tfrac{1}{2} A$

43 $\cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A} = \sqrt{\operatorname{cosec}^2 A - 1}$

44 $\cot A = \frac{\sin 2A}{1 - \cos 2A} = \frac{\sin 2A}{\operatorname{vers} 2A} = \frac{1 + \cos 2A}{\sin 2A}$

45 $\cot A = \frac{\tan \tfrac{1}{2} A}{\operatorname{exsec} A}$

46 $\operatorname{vers} A = 1 - \cos A = \sin A \tan \tfrac{1}{2} A = 2 \sin^2 \tfrac{1}{2} A$

47 $\operatorname{vers} A = \operatorname{exsec} A \cos A$

48 $\operatorname{exsec} A = \sec A - 1 = \tan A \tan \tfrac{1}{2} A = \frac{\operatorname{vers} A}{\cos A}$

49 $\sin \tfrac{1}{2} A = \sqrt{\frac{1 - \cos A}{2}} = \sqrt{\frac{\operatorname{vers} A}{2}}$

50 $\sin 2A = 2 \sin A \cos A$

51 $\cos \tfrac{1}{2} A = \sqrt{\frac{1 + \cos A}{2}}$

$\cos 2A = 2 \cos^2 A - 1 = \cos^2 A - \sin^2 A = 1 - 2 \sin^2 A$

General Formulas.

53. $\tan \frac{1}{2} A = \dfrac{\tan A}{1 + \sec A} = \operatorname{cosec} A - \cot A = \dfrac{1 - \cos A}{\sin A} = \sqrt{\dfrac{1 - \cos A}{1 + \cos A}}$

54. $\tan 2 A = \dfrac{2 \tan A}{1 - \tan^2 A}$

55. $\text{cot.} \frac{1}{2} A = \dfrac{\sin A}{\operatorname{vers} A} = \dfrac{1 + \cos A}{\sin A} = \dfrac{1}{\operatorname{cosec} A - \cot A}$

56. $\cot 2 A = \dfrac{\cot^2 A - 1}{2 \cot A}$

57. $\operatorname{vers} \frac{1}{2} A = \dfrac{\frac{1}{2} \operatorname{vers} A}{1 + \sqrt{1 - \frac{1}{2} \operatorname{vers} A}} = \dfrac{1 - \cos A}{2 + \sqrt{2(1 + \cos A)}}$

58. $\operatorname{vers} 2 A = 2 \sin^2 A = 2 \sin A \cos A \tan A$

59. $\operatorname{exsec} \frac{1}{2} A = \dfrac{1 - \cos A}{(1 + \cos A) + \sqrt{2(1 + \cos A)}}$

60. $\operatorname{exsec} 2 A = \dfrac{2 \tan^2 A}{1 - \tan^2 A}$

61. $\sin (A \pm B) = \sin A . \cos B \pm \sin B . \cos A$

62. $\cos (A \pm B) = \cos A . \cos B \mp \sin A . \sin B$

63. $\sin A + \sin B = 2 \sin \frac{1}{2} (A + B) \cos \frac{1}{2} (A - B)$

64. $\sin A - \sin B = 2 \cos \frac{1}{2} (A + B) \sin \frac{1}{2} (A - B)$

65. $\cos A + \cos B = 2 \cos \frac{1}{2} (A + B) \cos \frac{1}{2} (A - B)$

66. $\cos B - \cos A = 2 \sin \frac{1}{2} (A + B) \sin \frac{1}{2} (A - \mathrm{B})$

67. $\sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A = \sin (A + B) \sin (A - \mathrm{B})$

68. $\cos^2 A - \sin^2 B = \cos (A + B) \cos (A - B)$

69. $\tan A + \tan B = \dfrac{\sin (A + B)}{\cos A . \cos B}$

70. $\tan A - \tan B = \dfrac{\sin (A - B)}{\cos A . \cos B}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
			SIMPLE CURVE FORMULAS
1	16	D	$R = \frac{50}{\sin \frac{1}{2}D}$
2	17	R	$\sin \frac{1}{2}D = \frac{50}{\mathrm{R}}$
3	18	Δ, D	$L = 100\frac{\Delta}{D}$
4	19	D, L	$\Delta = \frac{DL}{100}$
5	20	Δ, L	$D = 100\frac{\Delta}{L}$
6	21	R, Δ	$T = R \tan \frac{1}{2}\Delta$
7	22	"	$C = 2\, R \sin \frac{1}{2}\Delta$
8	24	"	$M = R \operatorname{vers} \frac{1}{2}\Delta$
9	24	"	$E = R \operatorname{exsec} \frac{1}{2}\Delta$
10	25	T, Δ	$R = T \cot \frac{1}{2}\Delta$
11	26	"	$E = T \tan \frac{1}{4}\Delta$
12	......	"	$C = 2T \cos \frac{1}{2}\Delta$
13	......	"	$M = T \cot \frac{1}{2}\Delta \cdot \operatorname{vers} \frac{1}{2}\Delta$
14	27	E, Δ	$R = \frac{E}{\operatorname{exsec} \frac{1}{2}\Delta}$
15	28	"	$T = E \cot \frac{1}{4}\Delta$
16	29	R, d	$c = 2R \sin \frac{1}{2}d$
17	32	d, D	$c = 100\frac{d}{D}$ (approx.)
18	37	R	$t = \frac{(100)^2}{2R}$
19	38	R, c	$t_1 = \frac{c^2}{2R}$
20	39	R, c	$t_1 = \frac{c^2 t}{(100)^2}$
21	55	Bp, Δ	$AA' = BB' = \frac{Bp}{\sin \Delta}$
22	57	R, Bp, Δ	$R' = R + \frac{Bp}{\operatorname{vers} \Delta}$
23	59	BB', Δ	$R - R' = \frac{BB'}{\operatorname{exsec} \Delta}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
SIMPLE CURVE FORMULAS			
24	60	$R,\ R',\ \Delta$	$AA' = (R - R') \tan \Delta$
25	74	$D,\ b,\ L$	$D' = D \mp \frac{100}{L} \sin^{-1} \frac{2b}{L}$
26	......	$E,\ \Delta$	$C = 2E \frac{\sin \frac{1}{2}\Delta}{\text{exsec} \frac{1}{2}\Delta}$
27	......	"	$M = E \cos \frac{1}{2}\Delta$
28	......	$C,\ \Delta$	$R = \frac{C}{2 \sin \frac{1}{2}\Delta}$
29	......	"	$M = \frac{1}{2}C \tan \frac{1}{4}\Delta$
30	......	"	$T = \frac{C}{2 \cos \frac{1}{2}\Delta}$
31	......	"	$E = \frac{1}{2}C \frac{\text{exsec} \frac{1}{2}\Delta}{\sin \frac{1}{2}\Delta}$
32	......	$M,\ \Delta$	$R = \frac{M}{\text{vers} \frac{1}{2}\Delta}$
33	......	"	$C = 2M \cot \frac{1}{4}\Delta$
34	......	"	$T = M \frac{\tan \frac{1}{2}\Delta}{\text{vers} \frac{1}{2}\Delta}$
35	......	"	$E = \frac{M}{\cos \frac{1}{2}\Delta}$
36	......	$R,\ T$	$\tan \frac{1}{2}\Delta = \frac{T}{R}$
37	......	"	$\sin \frac{1}{2}\Delta = \frac{T}{\sqrt{T^2 + R^2}}$
38	......	$R,\ C$	$\sin \frac{1}{2}\Delta = \frac{C}{2R}$
39	......	"	$\cos \frac{1}{2}\Delta = \frac{1}{R}\sqrt{\left(R + \frac{C}{2}\right)\left(R - \frac{C}{2}\right)}$
40	......	$R,\ M$	$\text{vers} \frac{1}{2}\Delta = \frac{M}{R}$
41	......	"	$\cos \frac{1}{2}\Delta = \frac{R - M}{R}$
42	......	$R,\ E$	$\text{exsec} \frac{1}{2}\Delta = \frac{E}{R}$
43	......	"	$\cos \frac{1}{2}\Delta = \frac{R}{R + E}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
		SIMPLE CURVE FORMULAS	
44	......	T, C	$\cos \tfrac{1}{2}\Delta = \dfrac{C}{2T}$
45	......	..	$\tan \tfrac{1}{4}\Delta = \sqrt{\dfrac{2T-C}{2T+C}}$
46	......	T, E	$\tan \tfrac{1}{4}\Delta = \dfrac{E}{T}$
47	......	..	$\cos \tfrac{1}{2}\Delta = \dfrac{T^2-E^2}{T^2+E^2}$
48	......	C, M	$\tan \tfrac{1}{4}\Delta = \dfrac{2M}{C}$
49	......	..	$\cos \tfrac{1}{2}\Delta = \dfrac{C^2-4M^2}{C^2+4M^2}$
50	......	M, E	$\cos \tfrac{1}{2}\Delta = \dfrac{M}{E}$
51	......	..	$\tan \tfrac{1}{4}\Delta = \sqrt{\dfrac{E-M}{E+M}}$
52	......	R, T	$C = \dfrac{2TR}{\sqrt{T^2+R^2}}$
53	......	..	$M = R - \dfrac{R^2}{\sqrt{T^2+R^2}}$
54	......	..	$E = \sqrt{T^2+R^2} - R$
55	......	R, C	$T = \dfrac{CR}{2\sqrt{\left(R+\frac{C}{2}\right)\left(R-\frac{C}{2}\right)}}$
56	......	..	$M = R - \sqrt{(R+\tfrac{1}{2}C)(R-\tfrac{1}{2}C)}$
57	......	..	$E = \dfrac{R^2}{\sqrt{(R+\tfrac{1}{2}C)(R-\tfrac{1}{2}C)}} - R$
58	......	R, M	$T = \dfrac{R\sqrt{M(2R-M)}}{R-M}$
59	......	..	$C = 2\sqrt{M(2R-M)}$
60	......	..	$E = \dfrac{RM}{R-M}$
61	......	R, E	$T = \sqrt{E(2R+E)}$
62	......	..	$C = \dfrac{2R\sqrt{E(2R+E)}}{R+E}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
			Simple Curve Formulas
63	......	R, E	$M = \dfrac{RE}{R+E}$
64	......	T, C	$R = \dfrac{CT}{\sqrt{(2T+C)(2T-C)}}$
65	......	"	$M = \frac{1}{2}C\sqrt{\dfrac{2T-C}{2T+C}}$
66	......	"	$E = T\sqrt{\dfrac{2T-C}{2T+C}}$
67	......	T, E	$R = \dfrac{(T+E)(T-E)}{2E}$
68	......	"	$C = \dfrac{2T(T^2-E^2)}{T^2+E^2}$
69	......	"	$M = \dfrac{E(T^2-E^2)}{T^2+E^2}$
70	......	C, M	$R = \dfrac{M^2+(\frac{1}{2}C)^2}{2M}$
71	......	"	$T = \dfrac{C(C^2+4M^2)}{2(C^2-4M^2)}$
72	......	"	$E = M\dfrac{C^2+4M^2}{C^2-4M^2}$
73	......	M, E	$R = \dfrac{EM}{E-M}$
74	......	"	$T = E\sqrt{\dfrac{E+M}{E-M}}$
75	......	"	$C = 2M\sqrt{\dfrac{E+M}{E-M}}$
76	......	T, M	$R^3 - R^2\dfrac{M^2+T^2}{2M} + RT^2 - \frac{1}{2}MT^2 = 0$
77	......	"	$E^3 + E^2M - ET^2 + MT^2 = 0$
78	......	"	$C^3 + 2TC^2 + 4M^2C - 8M^2T = 0$
79	......	C, E	$R^3 + R^2\dfrac{4E^2-C^2}{8E} - R\dfrac{C^2}{4} - \dfrac{C^2E}{8} = 0$
80	......	"	$2T^3 - T^2C - 2TE^2 - CE^2 = 0$
81	......	"	$M^3 + M^2E + M\dfrac{C^2}{4} - \dfrac{C^2E}{4} = 0$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
			COMPOUND AND REVERSED CURVES
82	100	S_1, S_2, Δ	$\cot \tfrac{1}{2}\gamma = \frac{S_2 + S_1}{S_2 - S_1} \cot \tfrac{1}{2}\Delta$
83	101	Δ_1, Δ_2	$\Delta = \Delta_1 + \Delta_2$
84	102	$\left\{ \begin{matrix} S_1, S_2, \Delta_1, \\ \Delta_2, \gamma \end{matrix} \right\}$	$R_1 = \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\gamma - \cot \tfrac{1}{2}\Delta_1)$ $R_2 = \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\gamma + \cot \tfrac{1}{2}\Delta_2)$
85	103	$S_1, S_2, \Delta_1, \Delta_2$	$R_2 - R_1 = \tfrac{1}{2}(S_2 - S_1)(\cot \tfrac{1}{2}\Delta_2 + \cot \tfrac{1}{2}\Delta_1$
86	104	$\left\{ \begin{matrix} R_1, R_2, \\ S_1, S_2, \gamma \end{matrix} \right\}$	$\cot \tfrac{1}{2}\Delta_1 = \cot \tfrac{1}{2}\gamma - \frac{R_1}{\tfrac{1}{2}(S_2 - S_1)}$ $\cot \tfrac{1}{2}\Delta_2 = \frac{R_2}{\tfrac{1}{2}(S_2 - S_1)} - \cot \tfrac{1}{2}\gamma$
87	105	AB, Δ, γ	$\tfrac{1}{2}(S_2 - S_1) = \frac{\tfrac{1}{2}AB \sin \tfrac{1}{2}\gamma}{\sin \tfrac{1}{2}\Delta}$
88	106	$R_1, R_2, \Delta_1, \Delta_2$	$\tfrac{1}{2}(S_2 - S_1) = \frac{R_2 - R_1}{\cot \tfrac{1}{2}\Delta_2 + \cot \tfrac{1}{2}\Delta_1}$
89	107	$\left\{ \begin{matrix} R_1, R_2, S_1, \\ S_2, \Delta_1, \Delta_2 \end{matrix} \right\}$	$\cot \tfrac{1}{2}\gamma = \frac{R_1}{\tfrac{1}{2}(S_2 - S_1)} + \cot \tfrac{1}{2}\Delta_1$ $\cot \tfrac{1}{2}\gamma = \frac{R_2}{\tfrac{1}{2}(S_2 - S_1)} - \cot \tfrac{1}{2}\Delta_2$
90	108	S_1, S_2, Δ, γ	$\tfrac{1}{2}(S_2 + S_1) = \frac{\tfrac{1}{2}(S_2 - S_1) \cot \tfrac{1}{2}\gamma}{\cot \tfrac{1}{2}\Delta}$
91	109	S_1, S_2, Δ, γ	$\tfrac{1}{2}AB = \frac{\tfrac{1}{2}(S_2 - S_1) \sin \tfrac{1}{2}\Delta}{\sin \tfrac{1}{2}\gamma}$
92	206	p, r	$\text{vers } \Delta_r = \frac{\tfrac{1}{2}p}{r}$
93	207	p, Δ_r	$r = \frac{\tfrac{1}{2}p}{\text{vers } \Delta_r}$
94	208	p, Δ_r	$r_1 + r_2 = \frac{p}{\text{vers } \Delta_r}$
95	209	p, r_1, r_2	$\text{vers } \Delta_r = \frac{p}{r_1 + r_2}$
96	214	l, Δ_1, Δ_2	$r = \frac{l}{\tan \tfrac{1}{2}\Delta_1 + \tan \tfrac{1}{2}\Delta_2}$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
TURNOUTS			
97	220	F	$n \quad \frac{1}{2}\cot\frac{1}{2}F$
98	223	l, g, h, f, t, F, n	$L_a = l + [(g - h - f\sin F)]$ $\cot\frac{1}{2}(F+S) + f\cos F + nt$
99	224	g, h, f, F, S	$r + \frac{1}{2}g = \dfrac{g - h - f\sin F}{2\sin\frac{1}{2}(F-S)\sin\frac{1}{2}(F+S)}$
100	232	h, r, g, S	$o = h - (r + \frac{1}{2}g)\operatorname{vers} S$
101	240	g, n	$L_s = 2gn$
102	241	g, n	$r = 2gn^2 = L_s n$
103	244	p, g, F	$d = \dfrac{p-g}{\sin F} - g\cot F$
104	246	g, k, F, r	$o_1 = g + k\sin F - (r + \frac{1}{2}g)\operatorname{vers} F$
105	250	p, g, k, F	$r' - \frac{1}{2}g = \dfrac{p - g - k\sin F}{\operatorname{vers} F}$
106	271	g, r, F	$o = g - (r + \frac{1}{2}g)\operatorname{vers} F$
SPIRALS			
107	284	x, x', y, y'	$\tan a = \dfrac{x - x'}{y - y'}$
108	285	a, s	$i = a - s$
109	286	x, y, i	$SL = \dfrac{y}{\cos i} = \dfrac{x}{\sin i}$
110	287	x, y, s	$LE = \dfrac{x}{\sin s},\ SE = y - x\cot s$
111	290	x, R', s	$p = x - R'\operatorname{vers} s$
112	291	y, R', s	$q = y - R'\sin s$
113	292	y, x, Δ, R', s	$T_s = y + x\tan\frac{1}{2}\Delta + R'\dfrac{\sin(\frac{1}{2}\Delta - s)}{\cos\frac{1}{2}\Delta}$
114	294	R', n, c	$T_s = R'\tan\frac{1}{2}\Delta + \frac{1}{2}nc$ (approx.)
115	295	x, R', s, Δ	$E_s = \dfrac{x + R'(\cos s - \cos\frac{1}{2}\Delta)}{\cos\frac{1}{2}\Delta}$
116	299	R, R', x, s, Δ	$h\cos\frac{1}{2}\Delta = (R - R')\operatorname{vers}\frac{1}{2}\Delta - (x - R'\operatorname{vers} s)$
117	300	R, R', Δ, h	$p = (R - R')\operatorname{vers}\frac{1}{2}\Delta - h\cos\frac{1}{2}\Delta$
118	301	y, R, R', s, h, Δ	$d = y - R'\sin s - (R - R' + h)\sin\frac{1}{2}\Delta$
119	306	x, R, s, Δ	$-h = \dfrac{x - R\operatorname{vers} s}{\cos\frac{1}{2}\Delta} = \dfrac{p}{\cos\frac{1}{2}\Delta}$
120	307	q, h, p, Δ	$d = q + h\sin\frac{1}{2}\Delta = q + p\tan\frac{1}{2}\Delta$
121	308	p, p', Δ	$AC = \dfrac{p'}{\sin\Delta} - \dfrac{p}{\tan\Delta} \quad BC' = \dfrac{p}{\sin\Delta} - \dfrac{p'}{\tan\Delta}$
122	309	q, q', AC, BC'	$d = q + AC \qquad d' = q' + BC'$
123	315	p, Δ	$h = \dfrac{p}{\cos\frac{1}{2}\Delta}$
124	316	T, q, p, Δ	$T_s = T + q + p\tan\frac{1}{2}\Delta$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
		THE TEN-CHORD SPIRAL	
	A	R, L, l	$\frac{r}{R}=\frac{L}{l}$
	B	D, L, l	$\frac{d}{D}=\frac{l}{L}$
	C	L, D	$S=\frac{LD}{200}$
	D	S, L, l	$\frac{s}{S}=\frac{l^2}{L^2}$
	F′	D, L	$X=\frac{DL^3}{600}$
	G	x, l	$i=\frac{x}{l}=\frac{Dl^2}{600L}$ (approx.)
	H	s	$i=\frac{x}{3}$ (approx.)
	I	l, i	$y=l\cos i$
	K	x, y	$\tan I=\frac{X}{Y}$
	N	S, I	$I'=S-I$
	P	X, Y, R, s	$q=Y-R\sin s;\ p=X-R\operatorname{vers} s$
	Q	R, p, q, Δ	$T_s=(R+p)\tan\frac{1}{2}\Delta+q$
	R	R, p, q, Δ	$E_s=(R+p)\operatorname{exsec}\frac{1}{2}\Delta+p$
		EARTHWORK	
125	331	b, s, d	$x=\frac{1}{2}b+sd$
126	332	b, s, h, k	$\begin{cases} x=\frac{1}{2}b+sh \\ \quad=\frac{1}{2}b+sk \end{cases}$
127	336	b, s, d	$A=bd+sd^2$
128	337	b, m, n, d	$A=\frac{1}{2}(b+m+n)d$
129	340	b, h, k, m, n	$A=\frac{1}{2}d(m+n)+\frac{1}{4}b(h+k)$
130	341	b, s, d, m, n	$A=\frac{1}{2}\left(d+\frac{b}{2s}\right)(m+n)-\frac{b^2}{4s}$
131	342	A, A', l	$S=\frac{l}{27}\,\frac{(A+A')}{2}$
132	343	A, A', M	$S=\frac{l}{6\times 27}(A+4M+A')$
133	344	S_E, S_P	$C=S_E-S_P$

SERIAL NO.	TEXT NO.	GIVEN.	FORMULAS.
			EARTHWORK
134	346	$b,\ b',\ k,\ k'$	$C = \frac{l}{12 \times 27}(b - b')(k - k')$
135	348	$d,\ d',\ D,\ D'$	$C = \frac{l}{12 \times 27}(d - d')(D - D')$
136	352	$A,\ h$	$S = \frac{A}{27}\left(\frac{h_1 + h_2 + h_3}{3}\right)$
137	353	$A,\ h$	$S = \frac{A}{27}\left(\frac{h_1 + h_2 + h_3 + h_4}{4}\right)$
138	354	$A,\ s$	$S = A\frac{s_1 + 2s_2 + 3s_3 + 4s_4}{4 \times 27}$
139	355	$b,\ s,\ d$	$S = \frac{100}{27}(bd + sd^2)$
140	357	$b,\ a$	$S = \frac{50}{54}ba$
141	358	$b,\ d,\ m,$ $n,\ h,\ k$	$S_E = \frac{50}{54}d(m + n) + \frac{50}{54}\tfrac{1}{2}b(h + k)]$
142	359	$b,\ s,\ d,\ m,\ n$	$S_E = \frac{50}{54}\left(d + \frac{b}{2s}\right)(m + n) - \frac{50}{54}\frac{b^2}{2s}$
143	360	$d,\ d',\ D,\ D'$	$C = \frac{1}{3.24}(d - d')(D - D')$
144	365	$l,\ A,\ A',\ S$	$x = \frac{l^2(A - A')}{12 \times 27S}$
145	366	$l,\ A,\ A'$	$x = \frac{l}{6}\cdot\frac{A - A'}{A + A'}$
146	368	$C,\ \Delta$	$M = \tfrac{1}{2}C \cdot \tan \tfrac{1}{4}\Delta$
147	369	D	$m = \tfrac{1}{2}100 \tan \tfrac{1}{4}D$
148	370	$R,\ c$	$M = R - \sqrt{R^2 - \left(\frac{c}{2}\right)^2}$
149	373	$R,\ c$	$m_1 = \frac{c^2}{8R}$ (approx.)
150	375	n	$D = \frac{240}{n^2}$ (approx.)
151	376	n	$D = \frac{198}{n^2}$ (approx.)
152	377	$g,\ g',\ a$	$n = \frac{g - g'}{2a}$
153	378	$g,\ g',\ n$	$a = \frac{g - g'}{2n}$
154	381	$g,\ V,\ R$	$e = .06688\frac{gV^2}{R}$

Title.	Symbol.	Number.	] I
Ratio of circumference to diameter	π	3.1415927	0.
Reciprocal of same	$\frac{1}{\pi}$	0.3183099	9.
Degrees in arc of length equal to radius.	$\frac{180°}{\pi}$	57.295780	1.
Minutes " " " " " .	$\frac{10800'}{\pi}$	3437.7468	3.
Seconds " " " " " .	$\frac{648000''}{\pi}$	206264.81	5.
Length of 1° arc, radius unity..........	$\frac{\pi}{180°}$	.01745329	8.
Length of 1′ arc, " "	$\frac{\pi}{10800}$	.00029089	6.
Length of 1″ arc, " "	$\frac{\pi}{648000}$	.000004848	4.
Radius by which 1 foot of arc = 1 degree.		57.295780	1.
Radius " " $\frac{1}{10}$ " " = 1 minute.		343.77468	2.
Radius " " $\frac{1}{100}$ " " = 10 seconds		206.26481	2.
Factors for dividing a line into extreme and mean ratio		0.6180340	9.
		0.3819660	9.
Base of hyperbolic logarithms..........	ϵ	2.7182818	0.
Modulus of common system of logs = log ϵ	M	0.4342945	9.
Reciprocal of same = hyp. log. 10.......	$\frac{1}{M}$	2.3025851	0.
Length of seconds pendulum at New York in inches (at 125 feet above sea level)............................		39.10299	1.
Length of seconds pendulum at New York in feet......................		3.25858	0.
Acceleration due to gravity at New York	g	32.1609	1.
Square root of same..................	$\sqrt{g}$	5.67106	0.
Yards in 1 meter....................		1.093611	0.
Feet in 1 "		3.280834	0.
Inches in 1 "		39.37	1.
Meters in 1 foot.....................		0.304806	9.
Meters in 1 yard.....................		0.914418	9.
Meters in 1 mile.....................		1609.344	3.

Title.	Symbol.	Number.	Logarithm.
Cubic inches in 1 U. S. gallon		231.	2.3636120
“ “ “ 1 Imperial gallon		277.274	2.4429092
“ “ “ 1 U. S. bushel		2150.42	3.3325233
Cubic feet in 1 U. S. gallon		0.133681	9.1260683
“ “ “ 1 Imperial gallon		0.160459	9.2053855
“ “ “ 1 U. S. bushel		1.244456	0.0949796
Weight of 1 cub. foot of water, barom. 30 in. ther. 39°.83 Fah.; pounds		62.379	1.7950384
“ 62° “ “		62.321	1.7946349
Weight in grains, 1 cubic inch, at 62° Fah.		252.458	2.4021892
No. of grains in 1 pound avoir.		7000.	3.8450980
“ “ “ 1 ounce “		437.5	2.6409781

r = radius of circular arc;
l = length of arc;
a° = degrees in same arc.

$$\left.\begin{aligned} a^\circ &= \frac{l}{r}\cdot\frac{180^\circ}{\pi} \\ r &= \frac{l}{a^\circ}\cdot\frac{180^\circ}{\pi} \\ l &= a^\circ r\cdot\frac{\pi}{180^\circ} \end{aligned}\right\}$$

Radius by which the length of chord c in feet $= \frac{a'}{10}$ in minutes;

$$r = \frac{\frac{1}{2}a'}{10 \sin \frac{1}{2}a'}$$

Hyp. log x = com. log $x \times \frac{1}{M}$, or

$$\text{com. log (hyp. log } x) = \text{com. log (com. log } x) + 0.3622157$$

Com. log $x = M \times$ hyp. log x; or

$$\text{com. log (com. log } x) = 9.6377843 + \text{com. log (hyp. log } x)$$

Circumference of circle (radius $= r$) .... $2\pi r$

Area of circle .... πr^2

Area of sector (length of arc $= l$) .... $\frac{1}{2}lr$

Area of sector (angle of arc $= a^\circ$) .... $\frac{a}{360}\pi r^2$

Approximate area of segment (chord $= c$, mid. ord. $= m$) .... $\frac{2}{3}cm$

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD SPIRAL. TRANSIT AT *S*

S	1	2	3	4	5	6	7	8	9	10
0.0°	0° 00.00′	0° 00.0′	0° 00.0′	0° 00.0′	0° 00.0′	0° 00.0′	0° 00.0′	0° 00.0′	0° 00.0′	0° 00.0′
.1	00.02	00.1	00.2	00.3	00.5	00.7	01.0	01.3	01.6	02.0
.2	00.04	00.2	00.4	00.6	01.0	01.4	02.0	02.6	03.2	04.0
.3	00.06	00.2	00.5	01.0	01.5	02.2	02.9	03.8	04.9	06.0
.4	00.08	00.3	00.7	01.3	02.0	02.9	03.9	05.1	06.5	08.0
.5	00.10	00.4	00.9	01.6	02.5	03.6	04.9	06.4	08.1	10.0
.6	00.12	00.5	01.1	01.9	03.0	04.3	05.9	07.7	09.7	12.0
.7	00.14	00.6	01.3	02.2	03.5	05.0	06.9	09.0	11.3	14.0
.8	00.16	00.6	01.4	02.6	04.0	05.8	07.8	10.2	13.0	16.0
.9	00.18	00.7	01.6	02.9	04.5	06.5	08.8	11.5	14.6	18.0
1.0	00.20	0 00.8	0 01.8	0 03.2	0 05.0	0 07.2	0 09.8	0 12.8	0 16.2	0 20.0
.1	00.22	00.9	02.0	03.5	05.5	07.9	10.8	14.1	17.8	22.0
.2	00.24	01.0	02.2	03.8	06.0	08.6	11.8	15.4	19.4	24.0
.3	00.26	01.0	02.3	04.2	06.5	09.4	12.7	16.6	21.1	26.0
.4	00.28	01.1	02.5	04.5	07.0	10.1	13.7	17.9	22.7	28.0
.5	00.30	01.2	02.7	04.8	07.5	10.8	14.7	19.2	24.3	30.0
.6	00.32	01.3	02.9	05.1	08.0	11.5	15.7	20.5	25.9	32.0
.7	00.34	01.4	03.1	05.4	08.5	12.2	16.7	21.8	27.5	34.0
.8	00.36	01.4	03.2	05.8	09.0	13.0	17.6	23.0	29.2	36.0
.9	00.38	01.5	03.4	06.1	09.5	13.7	18.6	24.3	30.8	38.0
2.0	0 00.40	0 01.6	0 03.6	0 06.4	0 10.0	0 14.4	0 19.6	0 25.6	0 32.4	0 40.0
.1	00.42	01.7	03.8	06.7	10.5	15.1	20.6	26.9	34.0	42.0
.2	00.44	01.8	04.0	07.0	11.0	15.8	21.6	28.2	35.6	44.0
.3	00.46	01.8	04.1	07.4	11.5	16.6	22.5	29.4	37.3	46.0
.4	00.48	01.9	04.3	07.7	12.0	17.3	23.5	30.7	38.9	48.0
.5	00.50	02.0	04.5	08.0	12.5	18.0	24.5	32.0	40.5	50.0
.6	00.52	02.1	04.7	08.3	13.0	18.7	25.5	33.3	42.1	52.0
.7	00.54	02.2	04.9	08.6	13.5	19.4	26.5	34.6	43.7	54.0
.8	00.56	02.2	05.0	09.0	14.0	20.2	27.4	35.8	45.4	56.0
.9	00.58	02.3	05.2	09.3	14.5	20.9	28.4	37.1	47.0	58.0
3.0	0 00.60	0 02.4	0 05.4	0 09.6	0 15.0	0 21.6	0 29.4	0 38.4	0 48.6	1 00.0
.1	00.62	02.5	05.6	09.9	15.5	22.3	30.4	39.7	50.2	02.0
.2	00.64	02.6	05.8	10.2	16.0	23.0	31.4	41.0	51.8	04.0
.3	00.66	02.6	05.9	10.6	16.5	23.8	32.3	42.2	53.5	06.0
.4	00.68	02.7	06.1	10.9	17.0	24.5	33.3	43.5	55.1	08.0
.5	00.70	02.8	06.3	11.2	17.5	25.2	34.3	44.8	56.7	10.0
.6	00.72	02.9	06.5	11.5	18.0	25.9	35.3	46.1	58.3	12.0
.7	00.74	03.0	06.7	11.8	18.5	26.6	36.3	47.4	59.9	14.0
.8	00.76	03.0	06.8	12.2	19.0	27.4	37.2	48.6	1 01.6	16.0
.9	00.78	03.1	07.0	12.5	19.5	28.1	38.2	49.9	03.2	18.0
4.0	0 00.80	0 03.2	0 07.2	0 12.8	0 20.0	0 28.8	0 39.2	0 51.2	1 04.8	1 20.0
.1	00.82	03.3	07.4	13.1	20.5	29.5	40.2	52.5	06.4	22.0
.2	00.84	03.4	07.6	13.4	21.0	30.2	41.2	53.8	08.0	24.0
.3	00.86	03.4	07.7	13.8	21.5	31.0	42.1	55.0	09.7	26.0
.4	00.88	03.5	07.9	14.1	22.0	31.7	43.1	56.3	11.3	28.0
.5	00.90	03.6	08.1	14.4	22.5	32.4	44.1	57.6	12.9	30.0
.6	00.92	03.7	08.3	14.7	23.0	33.1	45.1	58.9	14.5	32.0
.7	00.94	03.8	08.5	15.0	23.5	33.8	46.1	1 00.2	16.1	34.0
.8	00.96	03.8	08.6	15.4	24.0	34.6	47.0	01.4	17.8	36.0
.9	00.98	03.9	08.8	15.7	24.5	35.3	48.0	02.7	19.4	38.0
5.0	0 01.00	0 04.0	0 09.0	0 16.0	0 25.0	0 36.0	0 49.0	1 04.0	1 21.0	1 40.0
.1	01.02	04.1	09.2	16.3	25.5	36.7	50.0	05.3	22.6	42.0
.2	01.04	04.2	09.4	16.6	26.0	37.4	51.0	06.6	24.2	44.0
.3	01.06	04.2	09.5	17.0	26.5	38.2	51.9	07.8	25.9	46.0
.4	01.08	04.3	09.7	17.3	27.0	38.9	52.9	09.1	27.5	48.0
.5	01.10	04.4	09.9	17.6	27.5	39.6	53.9	10.4	29.1	50.0
.6	01.12	04.5	10.1	17.9	28.0	40.3	54.9	11.7	30.7	52.0
.7	01.14	04.6	10.3	18.2	28.5	41.0	55.9	13.0	32.3	54.0
.8	01.16	04.6	10.4	18.6	29.0	41.8	56.8	14.2	34.0	56.0
.9	01.18	04.7	10.6	18.9	29.5	42.5	57.8	15.5	35.6	58.0
	01.20	0 04.8	0 10.8	0 19.2	0 30.0	0 43.2	0 58.8	1 16.8	1 37.2	2 00.0

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD SPIRAL. TRANSIT AT *S*

S	1	2	3	4	5	6	7	8	9	10
6.1°	0° 01.22′	0° 04.9′	0° 11.0′	0° 19.5′	0° 30.5′	0° 43.9′	0° 59.8′	1° 18.1′	1° 38.8′	2° 02.0′
.2	01.24	05.0	11.2	19.8	31.0	44.6	1 00.8	19.4	40.4	04.0
.3	01.26	05.0	11.3	20.2	31.5	45.4	01.7	20.6	42.1	06.0
.4	01.28	05.1	11.5	20.5	32.0	46.1	02.7	21.9	43.7	08.0
.5	01.30	05.2	11.7	20.8	32.5	46.8	03.7	23.2	45.3	10.0
.6	01.32	05.3	11.9	21.1	33.0	47.5	04.7	24.5	46.9	12.0
.7	01.34	05.4	12.1	21.4	33.5	48.2	05.7	25.8	48.5	14.0
.8	01.36	05.4	12.2	21.8	34.0	49.0	06.6	27.0	50.2	16.0
.9	01.38	05.5	12.4	22.1	34.5	49.7	07.6	28.3	51.8	18.0
7.0	0 01.40	0 05.6	0 12.6	0 22.4	0 35.0	0 50.4	1 08.6	1 29.6	1 53.4	2 20.0
.1	01.42	05.7	12.8	22.7	35.5	51.1	09.6	30.9	55.0	22.0
.2	01.44	05.8	13.0	23.0	36.0	51.8	10.6	32.2	56.6	24.0
.3	01.46	05.8	13.1	23.4	36.5	52.6	11.5	33.4	58.3	26.0
.4	01.48	05.9	13.3	23.7	37.0	53.3	12.5	34.7	59.9	28.0
.5	01.50	06.0	13.5	24.0	37.5	54.0	13.5	36.0	2 01.5	30.0
.6	01.52	06.1	13.7	24.3	38.0	54.7	14.5	37.3	03.1	32.0
.7	01.54	06.2	13.9	24.6	38.5	55.4	15.5	38.6	04.7	34.0
.8	01.56	06.2	14.0	25.0	39.0	56.2	16.4	39.8	06.4	36.0
.9	01.58	06.3	14.2	25.3	39.5	56.9	17.4	41.1	08.0	38.0
8.0	0 01.60	0 06.4	0 14.4	0 25.6	0 40.0	0 57.6	1 18.4	1 42.4	2 09.6	2 40.0
.1	01.62	06.5	14.6	25.9	40.5	58.3	19.4	43.7	11.2	42.0
.2	01.64	06.6	14.8	26.2	41.0	59.0	20.4	45.0	12.8	44.0
.3	01.66	06.6	14.9	26.6	41.5	59.8	21.3	46.2	14.5	46.0
.4	01.68	06.7	15.1	26.9	42.0	1 00.5	22.3	47.5	16.1	48.0
.5	01.70	06.8	15.3	27.2	42.5	01.2	23.3	48.8	17.7	50.0
.6	01.72	06.9	15.5	27.5	43.0	01.9	24.3	50.1	19.3	52.0
.7	01.74	07.0	15.7	27.8	43.5	02.6	25.3	51.4	20.9	54.0
.8	01.76	07.0	15.8	28.2	44.0	03.4	26.2	52.6	22.6	56.0
.9	01.78	07.1	16.0	28.5	44.5	04.1	27.2	53.9	24.2	58.0
9.0	0 01.80	0 07.2	0 16.2	0 28.8	0 45.0	1 04.8	1 28.2	1 55.2	2 25.8	3 00.0
.1	01.82	07.3	16.4	29.1	45.5	05.5	29.2	56.5	27.4	02.0
.2	01.84	07.4	16.6	29.4	46.0	06.2	30.2	57.8	29.0	04.0
.3	01.86	07.4	16.7	29.8	46.5	07.0	31.1	59.0	30.7	06.0
.4	01.88	07.5	16.9	30.1	47.0	07.7	32.1	2 00.3	32.3	08.0
.5	01.90	07.6	17.1	30.4	47.5	08.4	33.1	01.6	33.9	10.0
.6	01.92	07.7	17.3	30.7	48.0	09.1	34.1	02.9	35.5	12.0
.7	01.94	07.8	17.5	31.0	48.5	09.8	35.1	04.2	37.1	14.0
.8	01.96	07.8	17.6	31.4	49.0	10.6	36.0	05.4	38.8	16.0
.9	01.98	07.9	17.8	31.7	49.5	11.3	37.0	06.7	40.4	18.0
10.0	0 02.00	0 08.0	0 18.0	0 32.0	0 50.0	1 12.0	1 38.0	2 08.0	2 42.0	3 20.0
.1	02.02	08.1	18.2	32.3	50.5	12.7	39.0	09.3	43.6	21.9
.2	02.04	08.2	18.4	32.6	51.0	13.4	40.0	10.6	45.2	23.9
.3	02.06	08.2	18.5	33.0	51.5	14.2	40.9	11.8	46.8	25.9
.4	02.08	08.3	18.7	33.3	52.0	14.9	41.9	13.1	48.5	27.9
.5	02.10	08.4	18.9	33.6	52.5	15.6	42.9	14.4	50.1	29.9
.6	02.12	08.5	19.1	33.9	53.0	16.3	43.9	15.7	51.7	31.9
.7	02.14	08.6	19.3	34.2	53.5	17.0	44.9	17.0	53.3	33.9
.8	02.16	08.6	19.4	34.6	54.0	17.8	45.8	18.2	54.9	35.9
.9	02.18	08.7	19.6	34.9	54.5	18.5	46.8	19.5	56.6	37.9
11.0	0 02.20	0 08.8	0 19.8	0 35.2	0 55.0	1 19.2	1 47.8	2 20.8	2 58.2	3 39.9
.1	02.22	08.9	20.0	35.5	55.5	19.9	48.8	22.1	59.8	41.9
.2	02.24	09.0	20.2	35.8	56.0	20.6	49.8	23.4	3 01.4	43.9
.3	02.26	09.0	20.3	36.2	56.5	21.4	50.7	24.6	03.0	45.9
.4	02.28	09.1	20.5	36.5	57.0	22.1	51.7	25.9	04.7	47.9
.5	02.30	09.2	20.7	36.8	57.5	22.8	52.7	27.2	06.3	49.9
.6	02.32	09.3	20.9	37.1	58.0	23.5	53.7	28.5	07.9	51.9
.7	02.34	09.4	21.1	37.4	58.5	24.2	54.7	29.7	09.5	53.9
.8	02.36	09.4	21.2	37.8	59.0	25.0	55.6	31.0	11.1	55.9
.9	02.38	09.5	21.4	38.1	59.5	25.7	56.6	32.3	12.7	57.9
12.0	0 02.40	0 09.6	0 21.6	0 38.4	1 00.0	1 26.4	1 57.6	2 33.6	3 14.4	3 59.9

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD SPIRAL. TRANSIT AT *S*

S	1	2	3	4	5	6	7	8	9	10
12.1°	0° 02.42′	0° 09.7′	0° 21.8′	0° 38.7′	1° 00.5′	1° 27.1′	1° 58.6′	2° 34.9′	3° 16.0′	4° 01.9′
.2	02.44	09.8	22.0	39.0	01.0	27.8	59.5	36.1	17.6	03.9
.3	02.46	09.8	22.1	39.4	01.5	28.6	2 00.5	37.4	19.2	05.9
.4	02.48	09.9	22.3	39.7	02.0	29.3	01.5	38.7	20.8	07.9
.5	02.50	10.0	22.5	40.0	02.5	30.0	02.5	40.0	22.5	09.9
.6	02.52	10.1	22.7	40.3	03.0	30.7	03.5	41.3	24.1	11.9
.7	02.54	10.2	22.9	40.6	03.5	31.4	04.4	42.5	25.7	13.9
.8	02.56	10.2	23.0	41.0	04.0	32.2	05.4	43.8	27.3	15.9
.9	02.58	10.3	23.2	41.3	04.5	32.9	06.4	45.1	28.9	17.9
13.0	0 02.60	0 10.4	0 23.4	0 41.6	1 05.0	1 33.6	2 07.4	2 46.4	3 30.5	4 19.9
.1	02.62	10.5	23.6	41.9	05.5	34.3	08.4	47.7	32.2	21.9
.2	02.64	10.6	23.8	42.2	06.0	35.0	09.3	48.9	33.8	23.9
.3	02.66	10.6	23.9	42.6	06.5	35.8	10.3	50.2	35.4	25.9
.4	02.68	10.7	24.1	42.9	07.0	36.5	11.3	51.5	37.0	27.9
.5	02.70	10.8	24.3	43.2	07.5	37.2	12.3	52.8	38.6	29.9
.6	02.72	10.9	24.5	43.5	08.0	37.9	13.3	54.0	40.3	31.9
.7	02.74	11.0	24.7	43.8	08.5	38.6	14.2	55.3	41.9	33.9
.8	02.76	11.0	24.8	44.2	09.0	39.4	15.2	56.6	43.5	35.9
.9	02.78	11.1	25.0	44.5	09.5	40.1	16.2	57.9	45.1	37.9
14.0	0 02.80	0 11.2	0 25.2	0 44.8	1 10.0	1 40.8	2 17.2	2 59.2	3 46.7	4 39.9
.1	02.82	11.3	25.4	45.1	10.5	41.5	18.2	3 00.4	48.4	41.9
.2	02.84	11.4	25.6	45.4	11.0	42.2	19.1	01.7	50.0	43.9
.3	02.86	11.4	25.7	45.8	11.5	43.0	20.1	03.0	51.6	45.9
4	02.88	11.5	25.9	46.1	12.0	43.7	21.1	04.3	53.2	47.9
.5	02.90	11.6	26.1	46.4	12.5	44.4	22.1	05.6	54.8	49.9
.6	02.92	11.7	26.3	46.7	13.0	45.1	23.1	06.8	56.4	51.9
.7	02.94	11.8	26.5	47.0	13.5	45.8	24.0	08.1	58.1	53.9
.8	02.96	11.8	26.6	47.4	14.0	46.6	25.0	09.4	59.7	55.8
.9	02.98	11.9	26.8	47.7	14.5	47.3	26.0	10.7	4 01.3	57.8
15.0	0 03.00	0 12.0	0 27.0	0 48.0	1 15.0	1 48.0	2 27.0	3 12.0	4 02.9	4 59.8
.1	03.02	12.1	27.2	48.3	15.5	48.7	28.0	13.2	04.5	5 01.8
.2	03.04	12.2	27.4	48.6	16.0	49.4	28.9	14.5	06.1	03.8
.3	03.06	12.2	27.5	49.0	16.5	50.2	29.9	15.8	07.8	05.8
.4	03.08	12.3	27.7	49.3	17.0	50.9	30.9	17.1	09.4	07.8
.5	03.10	12.4	27.9	49.6	17.5	51.6	31.9	18.4	11.0	09.8
.6	03.12	12.5	28.1	49.9	18.0	52.3	32.9	19.6	12.6	11.8
.7	03.14	12.6	28.3	50.2	18.5	53.0	33.8	20.9	14.2	13.8
.8	03.16	12.6	28.4	50.6	19.0	53.7	34.8	22.2	15.9	15.8
.9	03.18	12.7	28.6	50.9	19.5	54.5	35.8	23.5	17.5	17.8
16.0	0 03.20	0 12.8	0 28.8	0 51.2	1 20.0	1 55.2	2 36.8	3 24.8	19.1	19.8
.1	03.22	12.9	29.0	51.5	20.5	55.9	37.8	26.0	20.7	21.8
.2	03.24	13.0	29.2	51.8	21.0	56.6	38.7	27.3	22.3	23.8
.3	03.26	13.0	29.3	52.2	21.5	57.3	39.7	28.6	23.9	25.8
.4	03.28	13.1	29.5	52.5	22.0	58.1	40.7	29.9	25.6	27.8
.5	03.30	13.2	29.7	52.8	22.5	58.8	41.7	31.1	27.2	29.8
.6	03.32	13.3	29.9	53.1	23.0	59.5	42.7	32.4	28.8	31.8
.7	03.34	13.4	30.1	53.4	23.5	2 00.2	43.6	33.7	30.4	33.8
.8	03.36	13.4	30.2	53.8	24.0	00.9	44.6	35.0	32.0	35.8
.9	03.38	13.5	30.4	54.1	24.5	01.7	45.6	36.3	33.6	37.8
17.0	0 03.40	0 13.6	0 30.6	0 54.4	1 25.0	2 02.4	2 46.6	3 37.5	4 35.3	5 39.8
.1	03.42	13.7	30.8	54.7	25.5	03.1	47.5	38.8	36.9	41.8
.2	03.44	13.8	31.0	55.0	26.0	03.8	48.5	40.1	38.5	43.7
.3	03.46	13.8	31.1	55.4	26.5	04.5	49.5	41.4	40.1	45.7
.4	03.48	13.9	31.3	55.7	27.0	05.3	50.5	42.7	41.7	47.7
.5	03.50	14.0	31.5	56.0	27.5	06.0	51.5	43.9	43.4	49.7
.6	03.52	14.1	31.7	56.3	28.0	06.7	52.4	45.2	45.0	51.7
.7	03.54	14.2	31.9	56.6	28.5	07.4	53.4	46.5	46.6	53.7
.8	03.56	14.2	32.0	57.0	29.0	08.1	54.4	47.8	48.2	55.7
9	03.58	14.3	32.2	57.3	29.5	08.9	55.4	49.0	49.8	57.7
0	0 03.60	0 14.4	0 32.4	0 57.6	1 30.0	2 09.6	2 56.4	3 50.3	4 51.5	5 59.7

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD SPIRAL. TRANSIT AT *S*

S	1	2	3	4	5	6	7	8	9	10
.1°	0° 03.62′	0° 14.5′	0° 32.6′	0° 57.9′	1° 30.5′	2° 10.3′	3° 57.3′	4° 51.6′	5° 53.1′	6° 01.7′
.2	03.64	14.6	32.8	58.2	31.0	11.0	58.3	52.9	54.7	03.7
.3	03.66	14.6	32.9	58.6	31.5	11.7	59.3	54.2	56.3	05.7
.4	03.68	14.7	33.1	58.9	32.0	12.5	3 00.3	55.4	57.9	07.7
.5	03.70	14.8	33.3	59.2	32.5	13.2	01.3	56.7	59.5	09.7
.6	03.72	14.9	33.5	59.5	33.0	13.9	02.2	58.0	5 01.2	11.7
.7	03.74	15.0	33.7	59.8	33.5	14.6	03.2	59.3	02.8	13.7
.8	03.76	15.0	33.8	1 00.2	34.0	15.3	04.2	4 00.6	04.4	15.7
.9	03.78	15.1	34.0	00.5	34.5	16.1	05.2	01.8	06.0	17.7
.0	0 03.80	0 15.2	0 34.2	1 00.8	1 35.0	2 16.8	3 06.2	4 03.1	5 07.6	6 19.7
.1	03.82	15.3	34.4	01.1	35.5	17.5	07.1	04.4	09.2	21.7
.2	03.84	15.4	34.6	01.4	36.0	18.2	08.1	05.7	10.9	23.7
.3	03.86	15.4	34.7	01.8	36.5	18.9	09.1	06.9	12.5	25.6
.4	03.88	15.5	34.9	02.1	37.0	19.7	10.1	08.2	14.1	27.6
.5	03.90	15.6	35.1	02.4	37.5	20.4	11.1	09.5	15.7	29.6
.6	03.92	15.7	35.3	02.7	38.0	21.1	12.0	10.8	17.3	31.6
.7	03.94	15.8	35.5	03.0	38.5	21.8	13.0	12.1	18.9	33.6
.8	03.96	15.8	35.6	03.4	39.0	22.5	14.0	13.3	20.6	35.6
.9	03.98	15.9	35.8	03.7	39.5	23.3	15.0	14.6	22.2	37.6
.0	0 04.00	0 16.0	0 36.0	1 04.0	1 40.0	2 24.0	3 16.0	4 15.9	5 22.8	39.6
.2	04.04	16.2	36.4	04.6	41.0	25.4	17.9	18.5	27.0	43.6
.4	04.08	16.3	36.7	05.3	42.0	26.9	19.9	21.0	30.3	47.6
.6	04.12	16.5	37.1	05.9	43.0	28.3	21.8	23.6	33.5	51.6
.8	04.16	16.6	37.4	06.6	44.0	29.7	23.8	26.1	36.7	55.6
.0	0 04.20	0 16.8	0 37.8	1 07.2	1 45.0	2 31.2	3 25.8	4 28.7	5 40.0	6 59.5
.2	04.24	17.0	38.2	07.8	46.0	32.6	27.7	31.2	43.2	7 03.5
.4	04.28	17.1	38.5	08.5	47.0	34.1	29.7	33.8	46.4	07.5
.6	04.32	17.3	38.9	09.1	48.0	35.5	31.6	36.4	49.7	11.5
.8	04.36	17.4	39.2	09.8	49.0	37.0	33.6	38.9	52.9	15.5
2.0	0 04.40	0 17.6	0 39.6	1 10.4	1 50.0	2 38.4	3 35.5	4 41.5	5 56.1	7 19.5
.2	04.44	17.8	40.0	11.0	51.0	39.8	37.5	44.0	59.3	23.5
4	04.48	17.9	40.3	11.7	52.0	41.3	39.5	46.6	6 02.6	27.5
.6	04.52	18.1	40.7	12.3	53.0	42.7	41.4	49.1	05.8	31.4
.8	04.56	18.2	41.0	13.0	54.0	44.2	43.4	51.7	09.0	35.4
3.0	0 04.60	0 18.4	0 41.4	1 13.6	1 55.0	2 45.6	3 45.3	4 54.2	6 12.3	7 39.4
.2	04.64	18.6	41.8	14.2	56.0	47.0	47.3	56.8	15.5	43.4
.4	04.68	18.7	42.1	14.9	57.0	48.5	49.2	59.4	18.7	47.4
.6	04.72	18.9	42.5	15.5	58.0	49.9	51.2	5 01.9	22.0	51.4
.8	04.76	19.0	42.8	16.2	59.0	51.4	53.2	04.5	25.2	55.3
.0	0 04.80	0 19.2	0 43.2	1 16.8	2 00.0	2 52.8	3 55.1	5 07.0	6 28.4	7 59.3
.2	04.84	19.4	43.6	17.4	01.0	54.2	57.1	09.6	31.7	8 03.3
.4	04.88	19.5	43.9	18.1	02.0	55.7	59.0	12.1	34.9	07.3
.6	04.92	19.7	44.3	18.7	03.0	57.1	4 01.0	14.7	38.1	11.3
.8	04.96	19.8	44.6	19.4	04.0	58.6	03.0	17.2	41.3	15.3
.0	0 05.00	0 20.0	0 45.0	1 20.0	2 05.0	3 00.0	4 04.9	5 19.8	6 44.6	8 19.2
.2	05.04	20.2	45.4	20.6	06.0	01.4	06.9	22.4	47.8	23.2
.4	05.08	20.3	45.7	21.3	07.0	02.9	08.8	24.9	51.0	27.2
.6	05.12	20.5	46.1	21.9	08.0	04.3	10.8	27.5	54.3	31.2
.8	05.16	20.6	46.4	22.6	09.0	05.8	12.8	30.0	57.5	35.2
.0	0 05.20	0 20.8	0 46.8	1 23.2	2 10.0	3 07.2	4 14.7	5 32.6	7 00.7	8 39.1
.2	05.24	21.0	47.2	23.8	11.0	08.6	16.7	35.1	04.0	43.1
.4	05.28	21.1	47.5	24.5	12.0	10.1	18.6	37.7	07.2	47.1
.6	05.32	21.3	47.9	25.1	13.0	11.5	20.6	40.2	10.4	51.1
.8	05.36	21.4	48.2	25.8	14.0	13.0	22.5	42.8	13.7	55.1
7.0	0 05.40	0 21.6	0 48.6	1 26.4	2 15.0	3 14.4	4 24.5	5 45.4	7 16.9	8 59.0
.2	05.44	21.8	49.0	27.0	16.0	15.8	26.5	47.9	20.1	9 03.0
.4	05.48	21.9	49.3	27.7	17.0	17.3	28.4	50.5	23.3	07.0
.6	05.52	22.1	49.7	28.3	18.0	18.7	30.4	53.0	26.6	11.0
.8	05.56	22.2	50.0	29.0	19.0	20.1	32.3	55.6	29.8	14.9
.0	0 05.60	0 22.4	0 50.4	1 29.6	2 20.0	3 21.5	4 34.3	5 58.1	7 33.0	9 18.4

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD SPIRAL. TRANSIT AT *S*

S	1	2	3	4	5	6	7	8	9	10
28.2°	0° 05.64′	0° 22.6′	0° 50.8′	1° 30.2′	2° 21.0′	3° 23.0′	4° 36.2′	6° 00.7′	7° 36.3′	9° 22.9′
.4	05.68	22.7	51.1	30.9	22.0	24.4	38.2	03.2	39.5	26.9
.6	05.72	22.9	51.5	31.5	23.0	25.9	40.2	05.8	42.7	30.9
.8	05.76	23.0	51.8	32.2	24.0	27.3	42.1	08.3	45.9	34.8
29.0	0 05.80	0 23.2	0 52.2	1 32.8	2 25.0	3 28.8	4 44.1	6 10.9	7 49.2	9 38.8
.2	05.84	23.4	52.6	33.4	26.0	30.2	46.0	13.4	52.4	42.8
.4	05.88	23.5	52.9	34.1	27.0	31.6	48.0	16.0	55.6	46.8
.6	05.92	23.7	53.3	34.7	28.0	33.1	49.9	18.6	58.8	50.7
.8	05.96	23.8	53.6	35.4	29.0	34.5	51.9	21.1	8 02.1	54.7
30.0	0 06.00	0 24.0	0 54.0	1 36.0	2 30.0	3 35.9	4 53.9	6 23.7	8 05.3	9 58.7
.2	06.04	24.2	54.4	36.6	31.0	37.4	55.8	26.2	08.5	10 02.6
.4	06.08	24.3	54.7	37.3	32.0	38.8	57.8	28.8	11.7	06.6
.6	06.12	24.5	55.1	37.9	33.0	40.3	59.7	31.3	15.0	10.6
.8	06.16	24.6	55.4	38.6	34.0	41.7	5 01.7	33.9	18.2	14.6
31.0	0 06.20	0 24.8	0 55.8	1 39.2	2 35.0	3 43.1	5 03.6	6 36.4	8 21.4	10 18.5
.2	06.24	25.0	56.2	39.8	36.0	44.6	05.6	39.0	24.6	22.5
.4	06.28	25.1	56.5	40.5	37.0	46.0	07.5	41.5	27.9	26.5
.6	06.32	25.3	56.9	41.1	38.0	47.5	09.5	44.1	31.1	30.4
.8	06.36	25.4	57.2	41.8	39.0	48.9	11.5	46.6	34.3	34.4
32.0	0 06.40	0 25.6	0 57.6	1 42.4	2 40.0	3 50.3	5 13.4	6 49.2	8 37.5	10 38.4
.2	06.44	25.8	58.0	43.0	41.0	51.8	15.4	51.7	40.8	42.4
.4	06.48	25.9	58.3	43.7	42.0	53.2	17.3	54.3	44.0	46.3
.6	06.52	26.1	58.7	44.3	43.0	54.7	19.3	56.8	47.2	50.3
.8	06.56	26.2	59.0	45.0	44.0	56.1	21.2	59.4	50.4	54.3
33.0	0 06.60	0 26.4	0 59.4	1 45.6	2 45.0	3 57.5	5 23.2	7 01.9	8 53.7	10 58.2
.2	06.64	26.6	59.8	46.2	46.0	59.0	25.1	04.5	56.9	11 02.2
.4	06.68	26.7	1 00.1	46.9	47.0	4 00.4	27.1	07.0	9 00.1	06.2
.6	06.72	26.9	00.5	47.5	48.0	01.8	29.1	09.6	03.3	10.1
.8	06.76	27.0	00.8	48.2	49.0	03.3	31.0	12.1	06.5	14.1
34.0	0 06.80	0 27.2	1 01.2	1 48.8	2 50.0	4 04.7	5 33.0	7 14.7	9 09.8	11 18.1
.2	06.84	27.4	01.6	49.4	51.0	06.2	34.9	17.2	13.0	22.0
.4	06.88	27.5	01.9	50.1	52.0	07.6	36.9	19.8	16.2	26.0
.6	06.92	27.7	02.3	50.7	53.0	09.0	38.8	22.4	19.4	30.0
.8	06.96	27.8	02.6	51.4	54.0	10.5	40.8	24.9	22.7	33.9
35.0	0 07.00	0 28.0	1 03.0	1 52.0	2 55.0	4 11.9	5 42.8	7 27.5	9 25.9	11 37.9
.2	07.04	28.2	03.4	52.6	56.0	13.3	44.7	30.0	29.1	41.8
.4	07.08	28.3	03.7	53.3	57.0	14.8	46.7	32.6	32.3	45.8
.6	07.12	28.5	04.1	53.9	58.0	16.2	48.6	35.1	35.5	49.8
.8	07.16	28.6	04.4	54.6	59.0	17.7	50.6	37.7	38.8	53.7
36.0	0 07.20	0 28.8	1 04.8	1 55.2	3 00.0	4 19.1	5 52.5	7 40.2	9 42.0	11 57.7
.2	07.24	29.0	05.2	55.8	01.0	20.5	54.5	42.8	45.2	12 01.7
.4	07.28	29.1	05.5	56.5	02.0	22.0	56.5	45.3	48.4	05.6
.6	07.32	29.3	05.9	57.1	03.0	23.4	58.4	47.8	51.6	09.6
.8	07.36	29.4	06.2	57.8	04.0	24.8	6 00.4	50.4	54.9	13.5
37.0	0 07.40	0 29.6	1 06.6	1 58.4	3 05.0	4 26.3	6 02.3	7 52.9	9 58.1	12 17.5
.2	07.44	29.8	07.0	59.0	06.0	27.7	04.3	55.5	10 01.3	21.5
.4	07.48	29.9	07.3	59.7	07.0	29.2	06.2	58.0	04.5	25.4
.6	07.52	30.1	07.7	2 00.3	08.0	30.6	08.2	8 00.6	07.7	29.4
.8	07.56	30.2	08.0	01.0	09.0	32.0	10.1	03.1	11.0	33.3
38.0	0 07.60	0 30.4	1 08.4	2 01.6	3 10.0	4 33.5	6 12.1	8 05.7	10 14.2	12 37.3
.2	07.64	30.6	08.8	02.2	11.0	34.9	14.0	08.2	17.4	41.2
.4	07.68	30.7	09.1	02.9	12.0	36.3	16.0	10.8	20.6	45.2
.6	07.72	30.9	09.5	03.5	13.0	37.8	18.0	13.3	23.8	49.2
.8	07.76	31.0	09.8	04.2	14.0	39.2	19.9	15.9	27.0	53.1
39.0	0 07.80	0 31.2	1 10.2	2 04.8	3 15.0	4 40.7	6 21.9	8 18.4	10 30.2	12 57.1
.2	07.84	31.4	10.6	05.4	16.0	42.1	23.8	21.0	33.5	13 01.0
.4	07.88	31.5	10.9	06.1	17.0	43.5	25.8	23.5	36.7	05.0
.6	07.92	31.7	11.3	06.7	18.0	45.0	27.7	26.1	39.9	08.9
.8	07.96	31.8	11.6	07.4	19.0	46.4	29.7	28.6	43.1	12.9
40.0	0 08.00	0 32.0	1 12.0	2 08.0	3 20.0	4 47.9	6 31.6	8 31.2	10 46.3	13 16.8

TABLE XLV.—DEFLECTIONS FOR TEN-CHORD SPIRAL. TRANSIT AT *S*

1	2	3	4	5	6	7	8	9	10
0° 08.04′	0° 32.2′	1° 12.4′	2° 08.6′	3° 20.9′	4° 49.3′	6° 33.6′	8° 33.7′	10° 49.5′	13° 20.8
08.08	32.3	12.7	09.3	21.9	50.7	35.5	36.3	52.8	24.7
08.12	32.5	13.1	09.9	22.9	52.2	37.5	38.8	56.0	28.7
08.16	32.6	13.4	10.6	23.9	53.6	39.5	41.4	59.2	32.6
0 08.20	0 32.8	1 13.8	2 11.2	3 24.9	4 55.0	6 41.4	8 43.9	11 02.4	13 36.6
08.24	33.0	14.2	11.8	25.9	56.5	43.4	46.5	05.6	40.5
08.28	33.1	14.5	12.5	26.9	57.9	45.3	49.0	08.8	44.5
08.32	33.3	14.9	13.1	27.9	59.4	47.3	51.6	12.0	48.4
08.36	33.4	15.2	13.8	28.9	5 00.8	49.2	54.1	15.2	52.4
0 08.40	0 33.6	1 15.6	2 14.4	3 29.9	5 02.2	6 51.2	8 56.6	11 18.4	13 56.3
08.44	33.8	16.0	15.0	30.9	03.7	53.1	59.2	21.7	14 00.3
08.48	33.9	16.3	15.7	31.9	05.1	55.1	9 01.7	24.9	04.2
08.52	34.1	16.7	16.3	32.9	06.5	57.0	04.3	28.1	08.2
08.56	34.2	17.0	17.0	33.9	08.0	59.0	06.8	31.3	12.1
0 08.60	0 34.4	1 17.4	2 17.6	3 34.9	5 09.4	7 01.0	9 09.4	11 34.5	16.1
08.64	34.6	17.8	18.2	35.9	10.9	02.9	11.9	37.7	20.0
08.68	34.7	18.1	18.9	36.9	12.3	04.9	14.5	40.9	24.0
08.72	34.9	18.5	19.5	37.9	13.7	06.8	17.0	44.1	27.9
08.76	35.0	18.8	20.2	38.9	15.2	08.8	19.5	47.4	31.8
0 08.80	0 35.2	1 19.2	2 20.8	3 39.9	5 16.6	7 10.7	9 22.1	11 50.6	14 35.8
08.84	35.4	19.6	21.4	40.9	18.0	12.7	24.6	53.8	39.7
08.88	35.5	19.9	22.1	41.9	19.5	14.6	27.2	57.0	43.7
08.92	35.7	20.3	22.7	42.9	20.9	16.6	29.7	12 00.2	47.6
08.96	35.8	20.6	23.4	43.9	22.4	18.5	32.3	03.4	51.6
0 09.00	0 36.0	1 21.0	2 24.0	3 44.9	5 23.8	7 20.5	9 34.8	12 06.6	14 55.5

BLE XLVI.—COEFFICIENTS FOR DEFLECTIONS FROM LOCAL TANGENT AT ANY POINT

flection Angle to hord-point Number.	Transit at Chord-point Number.										
	0 T.S.	1	2	3	4	5	6	7	8	9	10 S.C.
0 T.S.	0	2	8	18	32	50	72	98	128	162	200
1	1	0	5	14	27	44	65	90	119	152	189
2	4	4	0	8	20	36	56	80	108	140	176
3	9	10	7	0	11	26	45	68	95	126	161
4	16	18	16	10	0	14	32	54	80	110	144
5	25	28	27	22	13	0	17	38	63	92	125
6	36	40	40	36	28	16	0	20	44	72	104
7	49	54	55	52	45	34	19	0	23	50	81
8	64	70	72	70	64	54	40	22	0	26	56
9	81	88	91	90	85	76	63	46	25	0	29
10 S. C.	100	108	112	112	108	100	88	72	52	28	0

TABLE XLVII.—CORRECTIONS IN MINUTES FOR LARGE DEFLECTIONS

Eq. (*H*) $i = \frac{S}{3} \pm \text{correction}$

Number of point from position of transit

S	5	6	7	8	9	10	*S*
7°	....	....	....	....	.00	.01	7°
8	....	....	....	....	.01	.01	8
9	....	....	....	....	.01	.02	9
10	....	....	....	.00	.02	.03	10
11	....	....	....	.01	.03	.04	11
12	....	....	....	.01	.04	.06	12
13	....	....	....	.02	.05	.09	13
14	....	....	....	.02	.06	.12	14
15	....	....	.00	.03	.08	.15	15
16	....	....	.01	.04	.10	.19	16
17	....	....	.01	.05	.12	.24	17
18	....	....	.02	.07	.14	.29	18
19	....	....	.02	.08	.17	.34	19
20	....	....	.03	.10	.20	.40	20
21	....	....	.03	.12	.24	.47	21
22	....	....	.04	.13	.27	.54	22
23	....	....	.05	.15	.32	.62	23
24	....	.00	.06	.18	.36	.70	24
25	....	.01	.08	.20	.41	.79	25
26	....	.02	.09	.22	.47	.88	26
27	....	.02	.10	.25	.52	.98	27
28	....	.03	.11	.28	.58	1.09	28
29	....	.04	.13	.31	.64	1.21	29
30	....	.05	.15	.34	.71	1.34	30
31	....	.06	.16	.37	.78	1.47	31
32	....	.07	.18	.41	.86	1.62	32
33	....	.08	.20	.45	.94	1.77	33
34	....	.09	.22	.49	1.02	1.93	34
35	.00	.10	.25	.54	1.11	2.11	35
36	.01	.11	.27	.59	1.20	2.29	36
37	.01	.12	.29	.64	1.30	2.49	37
38	.02	.13	.33	.70	1.41	2.70	38
39	.03	.15	.35	.76	1.53	2.92	39
40	.04	.16	.38	.83	1.65	3.15	40
41	.05	.17	.42	.90	1.78	3.40	41
42	.06	.19	.46	.98	1.93	3.66	42
43	.07	.20	.50	1.06	2.08	3.93	43
44	.09	.22	.55	1.15	2.24	4.23	44
45	.10	.25	.59	1.25	2.42	4.54	45
S	5	6	7	8	9	10	*S*

TABLE XLVIII.—SPIRAL PARTS FOR 1° CURVE

L	S	q	p	Y	X	C	U	V
60	0.3°	30.00	0.03	60.00	0.10	60.00	40.00	20.00
80	0.4	40.00	0.05	80.00	0.19	80.00	53.33	26.67
100	0.5	50.00	0.07	100.00	0.29	100.00	66.67	33.33
120	0.6	60.00	0.10	120.00	0.42	120.00	80.00	40.00
140	0.7	70.00	0.14	140.00	0.57	140.00	93.33	46.67
160	0.8	80.00	0.19	160.00	0.74	160.00	106.67	53.33
180	0.9	90.00	0.24	180.00	0.94	180.00	120.00	60.00
200	1.0	100.00	0.29	199.99	1.16	200.00	133.34	66.67
220	1.1	110.00	0.35	219.99	1.41	220.00	146.67	73.34
240	1.2	120.00	0.42	239.99	1.68	240.00	160.00	80.00
260	1.3	130.00	0.49	259.99	1.97	259.99	173.34	86.67
280	1.4	140.00	0.57	279.98	2.28	279.99	186.67	93.34
300	1.5	149.99	0.65	299.98	2.62	299.99	200.01	100.01
320	1.6	159.99	0.74	319.98	2.98	319.99	213.34	106.67
340	1.7	169.99	0.84	339.97	3.36	339.99	226.68	113.33
360	1.8	179.99	0.94	359.97	3.77	359.98	240.01	120.00
380	1.9	189.99	1.05	379.96	4.20	379.98	253.34	126.67
400	2.0	199.99	1.16	399.95	4.65	399.98	266.68	133.35
420	2.1	209.99	1.28	419.94	5.13	419.98	280.02	140.02
440	2.2	219.99	1.41	439.94	5.63	439.97	293.36	146.69
460	2.3	229.99	1.54	459.93	6.15	459.97	306.69	153.36
480	2.4	239.98	1.68	479.92	6.70	479.96	320.03	160.03
500	2.5	249.98	1.82	499.91	7.27	499.96	333.37	166.70

SPIRAL PARTS FOR 1° 30′ CURVE

L	S	q	p	Y	X	C	U	V
60	0.45°	30.00	0.04	60.00	0.16	60.00	40.00	20.00
80	0.60	40.00	0.07	80.00	0.28	80.00	53.33	26.67
100	0.75	50.00	0.11	100.00	0.44	100.00	66.67	33.33
120	0.90	60.00	0.16	120.00	0.63	120.00	80.00	40.00
140	1.05	70.00	0.21	140.00	0.86	140.00	93.33	46.67
160	1.20	80.00	0.28	159.99	1.12	160.00	106.67	53.33
180	1.35	90.00	0.35	179.99	1.41	180.00	120.00	60.00
200	1.50	99.99	0.44	199.99	1.75	199.99	133.34	66.67
220	1.65	109.99	0.53	219.98	2.11	219.99	146.67	73.34
240	1.80	119.99	0.63	239.98	2.51	239.99	160.01	80.01
260	1.95	129.99	0.74	259.97	2.95	259.99	173.35	86.68
280	2.10	139.99	0.86	279.96	3.42	279.98	186.68	93.35
300	2.25	149.99	0.98	299.95	3.93	299.98	200.01	100.01
320	2.40	159.99	1.12	319.94	4.47	319.98	213.35	106.68
340	2.55	169.98	1.26	339.93	5.04	339.97	226.69	113.35
360	2.70	179.98	1.41	359.92	5.65	359.97	240.03	120.03
380	2.85	189.98	1.58	379.91	6.30	379.96	253.37	126.70
400	3.00	199.98	1.75	399.89	6.98	399.95	266.71	133.37
420	3.15	209.97	1.92	419.87	7.70	419.94	280.04	140.04
440	3.30	219.97	2.11	439.85	8.45	439.94	293.38	146.71
460	3.45	229.97	2.31	459.83	9.23	459.93	306.72	153.39
480	3.60	239.96	2.51	479.81	10.05	479.92	320.07	160.0[illegible]
500	3.75	249.96	2.73	499.79	10.90	499.91	333.41	166.[illegible]

TABLE XLVIII.—SPIRAL PARTS FOR 2° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	*V*
60	0.6°	30.00	0.05	60.00	0.21	60.00	40.00	20.00
80	0.8	40.00	0.09	80.00	0.37	80.00	53.33	26.67
100	1.0	50.00	0.15	100.00	0.58	100.00	66.67	33.33
120	1.2	60.00	0.21	119.99	0.84	120.00	80.00	40.00
140	1.4	70.00	0.29	139.99	1.14	140.00	93.33	46.67
160	1.6	79.99	0.37	159.99	1.49	159.99	106.67	53.33
180	1.8	89.99	0.47	179.98	1.88	179.99	120.00	60.00
200	2.0	99.99	0.58	199.98	2.33	199.99	133.34	66.67
220	2.2	109.99	0.70	219.97	2.82	219.99	146.67	73.34
240	2.4	119.99	0.84	239.96	3.35	239.98	160.01	80.01
260	2.6	129.98	0.98	259.95	3.93	259.98	173.35	86.68
280	2.8	139.98	1.14	279.93	4.56	279.97	186.69	93.35
300	3.0	149.98	1.31	299.92	5.24	299.96	200.03	100.02
320	3.2	159.98	1.49	319.90	5.96	319.96	213.36	106.69
340	3.4	169.97	1.68	339.88	6.72	339.95	226.70	113.36
360	3.6	179.97	1.88	359.86	7.54	359.94	240.04	120.03
380	3.8	189.96	2.10	379.83	8.40	379.93	253.38	126.71
400	4.0	199.96	2.33	399.81	9.31	399.91	266.72	133.39
420	4.2	209.95	2.56	419.78	10.26	419.90	280.07	140.07
440	4.4	219.95	2.81	439.74	11.26	439.89	293.42	146.75
460	4.6	229.94	3.08	459.71	12.31	459.87	306.77	153.43
480	4.8	239.93	3.35	479.66	13.40	479.85	320.12	160.11
500	5.0	249.93	3.63	499.62	14.54	499.83	333.47	166.79

SPIRAL PARTS FOR 2° 30′ CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	*V*
60	0.75°	30.00	0.07	60.00	0.26	60.00	40.00	20.00
80	1.00	40.00	0.12	80.00	0.47	80.00	53.33	26.67
100	1.25	50.00	0.18	100.00	0.73	100.00	66.67	33.33
120	1.50	59.99	0.26	119.99	1.05	120.00	80.00	40.00
140	1.75	69.99	0.36	139.99	1.43	139.99	93.33	46.67
160	2.00	79.99	0.47	159.98	1.86	159.99	106.67	53.34
180	2.25	89.99	0.59	179.97	2.36	179.99	120.01	60.00
200	2.50	99.99	0.73	199.96	2.91	199.98	133.35	66.68
220	2.75	109.98	0.88	219.95	3.52	219.98	146.68	73.35
240	3.00	119.98	1.05	239.93	4.19	239.97	160.02	80.02
260	3.25	129.98	1.23	259.92	4.91	259.96	173.36	86.69
280	3.50	139.97	1.42	279.90	5.70	279.95	186.70	93.37
300	3.75	149.97	1.64	299.87	6.54	299.94	200.05	100.04
320	4.00	159.96	1.86	319.84	7.44	319.93	213.39	106.72
340	4.25	169.96	2.10	339.81	8.40	339.92	226.73	113.40
360	4.50	179.95	2.36	359.78	9.42	359.90	240.08	120.07
380	4.75	189.94	2.62	379.74	10.50	379.89	253.42	126.75
400	5.00	199.93	2.91	399.70	11.63	399.87	266.77	133.43
420	5.25	209.93	3.21	419.65	12.82	419.85	280.12	140.11
440	5.50	219.92	3.52	439.60	14.07	439.82	293.48	146.80
460	5.75	229.91	3.84	459.54	15.38	459.80	306.84	153.49
480	6.00	239.90	4.19	479.48	16.74	479.77	320.19	160.17
500	6.25	249.88	4.54	499.41	18.17	499.74	333.54	166.86

TABLE XLVIII.—SPIRAL PARTS FOR 3° CURVE

L	S	q	p	Y	X	C	U	V
60	0.9°	30.00	0.08	60.00	0.31	60.00	40.00	20.00
80	1.2	39.99	0.14	80.00	0.56	80.00	53.33	26.67
100	1.5	49.99	0.22	99.99	0.87	100.00	66.67	33.34
120	1.8	59.99	0.31	119.99	1.26	119.99	80.00	40.00
140	2.1	69.99	0.43	139.98	1.71	139.99	93.34	46.67
160	2.4	79.99	0.56	159.97	2.23	159.99	106.68	53.34
180	2.7	89.98	0.71	179.96	2.83	179.98	120.01	60.01
200	3.0	99.98	0.87	199.95	3.49	199.98	133.35	66.68
220	3.3	109.98	1.06	219.93	4.22	219.97	146.69	73.35
240	3.6	119.97	1.26	239.91	5.03	239.96	160.03	80.08
260	3.9	129.97	1.47	259.88	5.90	259.95	173.38	86.71
280	4.2	139.96	1.71	279.85	6.84	279.93	186.72	93.38
300	4.5	149.95	1.96	299.82	7.85	299.92	200.07	100.06
320	4.8	159.95	2.23	319.78	8.93	319.90	213.41	106.74
340	5.1	169.94	2.52	339.73	10.08	339.88	226.76	113.41
360	5.4	179.93	2.83	359.68	11.30	359.86	240.11	120.09
380	5.7	189.92	3.15	379.63	12.59	379.84	253.47	126.77
400	6.0	199.91	3.49	399.56	13.95	399.81	266.82	133.47
420	6.3	209.89	3.85	419.50	15.38	419.78	280.18	140.16
440	6.6	219.88	4.22	439.42	16.88	439.74	293.54	146.85
460	6.9	229.87	4.61	459.34	18.45	459.71	306.90	153.55
480	7.2	239.85	5.02	479.25	20.08	479.67	320.27	160.24
500	7.5	249.83	5.45	499.15	21.79	499.62	333.64	166.94

SPIRAL PARTS FOR 3° 30′ CURVE

L	S	q	p	Y	X	C	U	V
60	1.05	30.00	0.09	60.00	0.37	60.00	40.00	20.00
80	1.40	39.99	0.16	80.00	0.65	80.00	53.33	26.67
100	1.75	49.99	0.25	99.99	1.02	100.00	66.67	33.34
120	2.10	59.99	0.37	119.98	1.47	119.99	80.01	40.01
140	2.45	69.99	0.50	139.97	2.00	139.99	93.35	46.68
160	2.80	79.98	0.65	159.96	2.61	159.98	106.68	53.35
180	3.15	89.98	0.82	179.95	3.30	179.98	120.02	60.02
200	3.50	99.97	1.02	199.93	4.07	199.97	133.36	66.69
220	3.85	109.97	1.23	219.90	4.93	219.96	146.70	73.36
240	4.20	119.96	1.47	239.87	5.86	239.94	160.05	80.04
260	4.55	129.95	1.72	259.84	6.88	259.93	173.40	86.72
280	4.90	139.95	1.99	279.80	7.98	279.91	186.75	93.40
300	5.25	149.94	2.29	299.75	9.16	299.89	200.10	100.08
320	5.60	159.93	2.60	319.70	10.42	319.87	213.44	106.76
340	5.95	169.92	2.94	339.64	11.76	339.84	226.79	113.44
360	6.30	179.90	3.30	359.57	13.18	359.81	240.15	120.14
380	6.65	189.89	3.67	379.49	14.69	379.78	253.51	126.83
400	7.00	199.87	4.07	399.41	16.27	399.74	266.88	133.52
420	7.35	209.86	4.49	419.31	17.94	419.70	280.25	140.22
440	7.70	219.84	4.92	439.21	19.69	439.65	293.61	146.92
460	8.05	229.82	5.38	459.10	21.51	459.60	306.98	153.63
480	8.40	239.80	5.86	478.98	23.42	479.55	320.36	160.[illegible]
500	8.75	249.77	6.36	498.84	25.41	499.49	333.74	

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	
60	1.2°	29.99	0.10	60.00	0.42	60.00	40.00	2
80	1.6	39.99	0.19	79.99	0.74	80.00	53.33	26
100	2.0	49.99	0.29	99.99	1.16	99.99	66.67	33
120	2.4	59.98	0.42	119.98	1.68	119.99	80.00	40
140	2.8	69.98	0.57	139.97	2.28	139.99	93.34	46
160	3.2	79.98	0.74	159.95	2.98	159.98	106.68	53
180	3.6	89.97	0.94	179.93	3.77	179.97	120.02	60
200	4.0	99.96	1.16	199.90	4.65	199.96	133.37	66
220	4.4	109.96	1.41	219.87	5.63	219.94	146.71	73
240	4.8	119.95	1.67	239.83	6.70	239.93	160.05	80
260	5.2	129.94	1.96	259.79	7.86	259.91	137.41	86
280	5.6	139.93	2.28	279.73	9.12	279.88	186.76	93
300	6.0	149.92	2.62	299.67	10.46	299.86	200.12	100
320	6.4	159.90	2.98	319.60	11.90	319.82	213.47	106
340	6.8	169.89	3.36	339.52	13.44	339.79	226.83	113
360	7.2	179.87	3.77	359.44	15.06	359.75	240.20	120
380	7.6	189.85	4.20	379.34	16.78	379.71	253.57	126
400	8.0	199.83	4.65	399.23	18.59	399.66	266.94	133
420	8.4	209.81	5.12	419.10	20.49	419.60	280.32	140
440	8.8	219.79	5.62	438.97	22.49	439.54	293.70	147
460	9.2	229.76	6.15	458.82	24.58	459.48	307.08	153
480	9.6	239.73	6.69	478.66	26.76	479.41	320.47	160
500	10.0	249.70	7.26	498.49	29.03	499.33	333.87	167

SPIRAL PARTS FOR 4° 30′ CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	
60	1.35°	29.99	0.12	60.00	0.47	60.00	40.00	20
80	1.80	39.99	0.21	79.99	0.84	80.00	53.33	26
100	2.25	49.98	0.33	99.98	1.31	99.99	66.67	33
120	2.70	59.98	0.47	119.97	1.88	119.99	80.01	40
140	3.15	69.98	0.64	139.96	2.57	139.98	93.35	46
160	3.60	79.97	0.84	159.94	3.35	159.97	106.69	53
180	4.05	89.96	1.06	179.91	4.24	179.96	120.03	60
200	4.50	99.95	1.31	199.88	5.23	199.95	133.38	66
220	4.95	109.95	1.58	219.84	6.33	219.93	146.72	73
240	5.40	119.93	1.88	239.79	7.54	239.91	160.07	80
260	5.85	129.92	2.21	259.73	8.84	259.88	173.42	86
280	6.30	139.91	2.56	279.66	10.25	279.85	186.78	93
300	6.75	149.89	2.94	299.59	11.77	299.82	200.14	100
320	7.20	159.88	3.35	319.50	13.39	319.78	213.51	106
340	7.65	169.86	3.78	339.40	15.11	339.73	226.88	113.
360	8.10	179.84	4.23	359.29	16.94	359.68	240.25	120.
380	8.55	189.81	4.72	379.16	18.87	379.63	253.63	126.
400	9.00	199.79	5.23	399.02	20.91	399.57	267.01	133.
420	9.45	209.76	5.76	418.87	23.05	419.50	280.40	140.
440	*9.90*	219.73	6.32	438.70	25.29	439.42	293.80	147.
460	*10.35*	229.70	6.91	458.51	27.63	459.34	307.20	153.
480	*10.80*	239.66	7.53	478.31	30.08	479.25	320.60	160.
	11.25	249.63	8.17	498.09	32.64	499.15	334.01	167.

TABLE XLVIII.—SPIRAL PARTS FOR 5° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	*V*
60	1.5°	29.99	0.13	60.00	0.52	60.00	40.00	20.00
80	2.0	39.99	0.23	79.99	0.93	80.00	53.33	26.67
100	2.5	49.98	0.36	99.98	1.45	99.99	66.67	33.34
120	3.0	59.98	0.52	119.97	2.09	119.99	80.00	40.01
140	3.5	69.97	0.71	139.95	2.85	139.98	93.35	46.68
160	4.0	79.96	0.93	159.92	3.72	159.97	106.69	53.36
180	4.5	89.95	1.18	179.89	4.71	179.95	120.03	60.04
200	5.0	99.94	1.45	199.85	5.81	199.93	133.39	66.72
220	5.5	109.93	1.76	219.80	7.03	219.91	146.74	73.39
240	6.0	119.92	2.09	239.74	8.37	239.88	160.09	80.08
260	6.5	129.90	2.45	259.67	9.82	259.85	173.45	86.77
280	7.0	139.89	2.85	279.58	11.39	279.82	186.81	93.46
300	7.5	149.87	3.27	299.49	13.07	299.77	200.18	100.16
320	8.0	159.85	3.72	319.38	14.87	319.73	213.55	106.86
340	8.5	169.83	4.20	339.26	16.79	339.67	226.93	113.57
360	9.0	179.80	4.70	359.12	18.82	359.61	240.31	120.29
380	9.5	189.77	5.24	378.96	20.96	379.54	253.70	127.01
400	10.0	199.74	5.81	398.79	23.22	399.47	267.10	133.73

SPIRAL PARTS FOR 6° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	*V*
60	1.8°	29.99	0.16	59.99	0.63	60.00	40.00	20.00
80	2.4	39.98	0.28	79.99	1.12	79.99	53.33	26.67
100	3.0	49.97	0.44	99.97	1.74	99.99	66.67	33.34
120	3.6	59.96	0.63	119.95	2.51	119.98	80.00	40.01
140	4.2	69.96	0.85	139.93	3.42	139.97	93.35	46.68
160	4.8	79.95	1.12	159.89	4.47	159.95	106.70	53.36
180	5.4	89.93	1.41	179.84	5.65	179.93	120.05	60.05
200	6.0	99.92	1.74	199.78	6.98	199.90	133.41	66.74
220	6.6	109.90	2.11	219.71	8.44	219.87	146.77	73.43
240	7.2	119.88	2.51	239.62	10.04	239.83	160.13	80.12
260	7.8	129.86	2.94	259.52	11.78	259.79	173.50	86.82
280	8.4	139.84	3.41	279.40	13.66	279.74	186.87	93.52
300	9.0	149.81	3.92	299.26	15.68	299.68	200.26	100.24
320	9.6	159.78	4.46	319.11	17.84	319.61	213.65	106.96
340	10.2	169.75	5.03	338.93	20.13	339.53	227.05	113.68
360	10.8	179.71	5.64	358.73	22.56	359.44	240.45	120.41
380	11.4	189.67	6.28	378.51	25.13	379.34	253.87	127.15
400	12.0	199.63	6.96	398.26	27.84	399.23	267.29	133.90

SPIRAL PARTS FOR 7° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	*V*
60	2.1°	29.98	0.18	59.99	0.73	60.00	40.00	20.00
80	2.8	39.97	0.33	79.98	1.30	79.99	53.34	26.67
100	3.5	49.96	0.51	99.96	2.04	99.98	66.68	33.35
120	4.2	59.95	0.73	119.94	2.93	119.97	80.01	40.02
140	4.9	69.94	1.00	139.90	3.99	139.96	93.37	46.70
160	5.6	79.93	1.30	159.85	5.21	159.93	106.72	53.38
180	6.3	89.91	1.65	179.78	6.59	179.90	120.06	60.06
200	7.0	99.89	2.03	199.70	8.14	199.87	133.44	66.75
220	7.7	109.87	2.46	219.61	9.84	219.83	146.81	73.45
240	8.4	119.84	2.92	239.49	11.71	239.77	160.18	80.17
260	9.1	129.81	3.43	259.35	13.74	259.71	173.56	86.88
280	9.8	139.78	3.98	279.19	15.93	279.64	186.95	93.59
300	10.5	149.74	4.57	299.00	18.28	299.56	200.36	100.32
320	11.2	159.70	5.20	318.79	20.79	319.46	213.76	107.05
340	11.9	169.66	5.87	338.54	23.47	339.36	227.18	113.80
360	12.6	179.61	6.57	358.27	26.30	359.24	240.61	120.56
380	13.3	189.55	7.32	377.97	29.29	379.10	254.05	127.33
400	14.0	199.49	8.12	399.63	32.44	398.95	267.51	134.[illegible]

TABLE XLVIII.—SPIRAL PARTS FOR 8° CU

	S	*q*	*p*	*Y*	*X*	*C*	*U*
60	2.4°	29.97	0.21	59.99	0.84	60.00	40.00
80	3.2	39.96	0.37	79.98	1.49	79.99	53.34
00	4.0	49.95	0.57	99.95	2.33	99.93	66.68
120	4.8	59.94	0.84	119.92	3.35	119.96	80.01
140	5.6	69.92	1.14	139.87	4.56	139.94	93.38
160	6.4	79.90	1.49	159.80	5.95	159.91	106.74
180	7.2	89.88	1.88	179.72	7.53	179.88	120.10
200	8.0	99.86	2.32	199.61	9.30	199.83	133.47
220	8.8	109.83	2.81	219.48	11.24	219.77	146.85
240	9.6	119.79	3.34	239.33	13.38	239.70	160.24
260	10.4	129.76	3.92	259.15	15.69	259.62	173.64
280	11.2	139.71	4.54	278.94	18.20	279.53	187.04
300	12.0	149.67	5.22	298.69	20.88	299.42	200.46
320	12.8	159.61	5 93	318.42	23.75	319.30	213.89
340	13.6	169.55	6.70	338.10	26.79	339.16	227.34
360	14.4	179.49	7.51	357.75	30.03	359.00	240.81
380	15.2	189.42	8.36	377.35	33.44	378.83	254.28
400	16.0	199.34	9.27	397.91	37.03	398.63	267.77

SPIRAL PARTS FOR 9° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*
60	2.7°	29.97	0.23	59.99	0.94	59.99	40.01
80	3.6	39.95	0.42	79.97	1.68	79.99	53.34
100	4.5	49.94	0.65	99.94	2.62	99.97	66.69
120	5.4	59.92	0.94	119.89	3.77	119.95	80.02
140	6.3	69.90	1.28	139.83	5.13	139.93	93.39
160	7.2	79.88	1.67	159.75	6.69	159.89	106.76
180	8.1	89.85	2.11	179.64	8.47	179.84	120.13
200	9.0	99.82	2.61	199.51	10.45	199.78	133.51
220	9.9	109.78	3.16	219.35	12.64	219.71	146.90
240	10.8	119.74	3.75	239.15	15.04	239.63	160.3
260	11.7	129.69	4.40	258.92	17.65	259.52	173.7
280	12.6	139.64	5.11	278.66	20.46	279.41	187.1
300	13.5	149.58	5.86	298.35	23.47	299.27	200.5
320	14.4	159.51	6.67	318.00	26.69	319.11	214.
340	15.3	169.44	7.53	337.60	30.11	338.94	227.
360	16.2	179.35	8.43	357.15	33.74	358.74	241.
380	17.1	189.26	9.39	376.66	37.57	378.52	254.
400	18.0	199.16	10.41	396.09	41.60	398.27	268

SPIRAL PARTS FOR 10° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*
60	3.0°	29.96	0.26	59.98	1.05	59.99
80	4.0	39.94	0.46	79.96	1.86	79.98
100	5.0	49.92	0.72	99.92	2.91	99.97
120	6.0	59.90	1.04	119.87	4.19	119.94
140	7.0	69.88	1.42	139.79	5.70	139.91
160	8.0	79.85	1.85	159.69	7.44	159.86
180	9.0	89.81	2.35	179.56	9.41	179.81
200	10.0	99.78	2.90	199.40	11.61	199.73
220	11.0	109.73	3.50	219.20	14.04	219.64
240	12.0	119.68	4.17	238.96	16.70	239.54
260	13.0	129.62	4.89	258.67	19.59	259.41
280	14.0	139.56	5.67	278.34	22.71	279.27
300	15.0	149.48	6.51	297.96	26.05	299.10
320	16.0	159.40	7.40	317.53	29.62	318.91
340	17.0	169.31	8.35	337.04	33.42	338.69
	18.0	179.20	9.36	356.49	37.44	358.44
	19.0	189.09	10.42	375.87	41.68	378.1
	20.0	198.97	11.55	395.18	46.14	397.8

TABLE XLVIII.—SPIRAL PARTS FOR 12° CURVE

L	S	q	p	Y	X	C	U	V
60	3.6°	29.94	0.31	59.98	1.26	59.99	40.01	20.01
80	4.8	39.92	0.56	79.94	2.23	79.98	53.35	26.68
100	6.0	49.89	0.87	99.89	3.49	99.95	66.70	33.37
120	7.2	59.86	1.25	119.81	5.02	119.92	80.06	40.06
140	8.4	69.82	1.70	139.70	6.83	139.87	93.44	46.76
160	9.6	79.78	2.22	159.55	8.92	159.80	106.83	53.48
180	10.8	89.73	2.81	179.37	11.28	179.72	120.23	60.21
200	12.0	99.68	3.47	199.13	13.92	199.62	133.64	66.95
220	13.2	109.61	4.19	218.84	16.83	219.49	147.08	73.71
240	14.4	119.54	4.99	238.50	20.02	239.34	160.54	80.49
260	15.6	129.46	5.85	259.09	23.47	259.16	174.02	87.29
280	16.8	139.36	6.79	277.62	27.20	278.94	187.53	94.12
300	18.0	149.25	7.79	297.07	31.20	298.70	201.05	100.96
320	19.2	159.14	8.86	316.45	35.46	318.43	214.61	107.83
340	20.4	169.00	9.99	335.74	39.99	338.11	228.21	114.73
360	21.6	178.86	11.20	354.95	44.79	357.76	241.82	121.67
380	22.8	188.68	12.47	374.06	49.86	377.37	255.48	128.63
400	24.0	198.52	13.81	393.08	55.16	396.93	269.18	135.62

SPIRAL PARTS FOR 14° CURVE

L	S	q	p	Y	X	C	U	V
60	4.2°	29.92	0.36	59.97	1.47	59.99	40.01	20.01
80	5.6	39.89	0.65	79.92	2.60	79.97	53.36	26.69
100	7.0	49.85	1.01	99.85	4.07	99.93	66.72	33.38
120	8.4	59.81	1.45	119.74	5.86	119.89	80.09	40.08
140	9.8	69.76	1.98	139.59	7.97	139.82	93.48	46.80
160	11.2	79.70	2.58	159.39	10.40	159.73	106.89	53.53
180	12.6	89.64	3.27	179.14	13.15	179.62	120.31	60.28
200	14.0	99.56	4.03	198.82	16.22	199.48	133.76	67.05
220	15.4	109.47	4.88	218.42	19.61	219.30	147.23	73.85
240	16.8	119.37	5.80	237.96	23.32	239.10	160.73	80.67
260	18.2	129.26	6.81	257.40	27.33	258.85	174.26	87.52
280	19.6	139.13	7.89	276.76	31.67	278.56	187.83	94.40
300	21.0	148.99	9.06	296.02	36.31	298.24	201.44	101.31
320	22.4	158.83	10.30	315.17	41.25	317.86	214.08	108.28
340	23.8	168.65	11.62	334.21	46.51	337.43	228.76	115.25
360	25.2	178.45	13.02	353.13	52.06	356.95	242.50	122.28
380	26.6	188.23	14.49	371.93	57.92	376.42	256.27	129.35
400	28.0	197.99	16.05	390.60	64.07	395.82	270.10	136.47

SPIRAL PARTS FOR 15° CURVE

L	S	q	p	Y	X	C	U	V
60	4.5°	29.91	0.39	59.96	1.57	59.98	40.01	20.01
80	6.0	39.87	0.69	79.91	2.79	79.96	53.36	26.69
100	7.5	49.83	1.08	99.83	4.36	99.92	66.73	33.39
120	9.0	59.78	1.56	119.71	6.27	119.87	80.11	40.10
140	10.5	69.73	2.12	139.53	8.53	139.79	93.50	46.82
160	12.0	79.66	2.76	159.30	11.14	159.69	106.91	53.56
180	13.5	89.58	3.50	179.01	14.08	179.56	120.35	60.32
200	15.0	99.50	4.32	198.64	17.37	199.40	133.82	67.11
220	16.5	109.40	5.22	218.19	21.00	219.20	147.31	73.92
240	18.0	119.28	6.21	237.66	24.96	238.96	160.84	80.77
260	19.5	129.15	7.28	257.02	29.26	258.68	174.40	87.64
280	21.0	139.00	8.44	276.28	33.89	278.35	188.01	93.56
300	22.5	148.84	9.69	295.43	38.84	297.97	201.65	101.51
320	24.0	158.65	11.01	314.46	44.13	317.54	215.34	108.50
340	25.5	168.45	12.42	333.36	49.74	337.05	229.08	115.54
360	27.0	178.22	13.92	352.13	55.67	356.50	242.87	122.62
380	28.5	187.97	15.49	370.75	61.92	375.89	256.72	129.76
400	30.0	197.69	17.15	389.23	68.48	395.21	270.63	136.95

TABLE XLVIII.—SPIRAL PARTS FOR 16° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	*V*
60	4.8°	29.90	0.41	59.96	1.67	59.98	40.01	20.01
80	6.4	39.85	0.74	79.90	2.98	79.96	53.37	26.70
100	8.0	49.81	1.15	99.81	4.65	99.91	66.74	33.40
120	9.6	59.75	1.66	119.67	6.69	119.85	80.12	40.12
140	11.2	69.69	2.26	139.47	9.10	139.77	93.52	46.84
160	12.8	79.61	2.95	149.21	11.87	159.65	106.95	53.59
180	14.4	89.53	3.73	178.87	15.01	179.50	120.40	60.37
200	16.0	99.43	4.60	198.45	18.51	199.32	133.89	67.17
220	17.6	109.31	5.56	217.94	22.38	219.09	147.40	74.01
240	19.2	119.18	6.61	237.33	26.60	238.82	160.95	80.87
260	20.8	129.04	7.76	256.61	31.17	258.50	174.55	87.78
280	22.4	138.87	8.99	275.77	36.10	278.13	188.19	94.73
300	24.0	148.68	10.31	294.81	41.37	297.70	201.88	101.72
320	25.6	158.47	11.72	313.70	46.99	317.20	215.62	108.76
340	27.2	168.24	13.23	332.46	52.95	336.65	229.42	115.85
360	28.8	177.98	14.81	351.06	59.25	356.02	243.28	122.99
380	30.4	187.70	16.49	369.50	65.89	375.49	257.21	130.20
400	32.0	197.38	17.70	387.77	72.85	394.55	271.19	137.47

SPIRAL PARTS FOR 18° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	*V*
60	5.4°	29.87	0.47	59.95	1.88	59.98	40.02	20.02
80	7.2	39.82	0.83	79.87	3.35	79.94	53.38	26.71
100	9.0	49.75	1.29	99.75	5.23	99.89	66.75	33.41
120	10.8	59.68	1.86	119.58	7.52	119.81	80.15	40.14
140	12.6	69.60	2.53	139.33	10.23	139.70	93.57	46.88
160	14.4	79.51	3.30	159.00	13.34	159.56	107.02	53.66
180	16.2	89.40	4.18	178.57	16.87	179.37	120.51	60.47
200	18.0	99.28	5.16	198.05	20.80	199.14	134.03	67.31
220	19.8	109.13	6.23	217.40	25.13	218.85	147.60	74.19
240	21.6	118.97	7.41	236.63	29.86	238.51	161.22	81.11
260	23.4	128.78	8.69	255.72	34.98	258.10	174.88	88.08
280	25.2	138.57	10.07	274.66	40.49	277.63	188.61	95.11
300	27.0	148.34	11.55	293.44	46.39	297.09	202.39	102.19
320	28.8	158.07	13.13	312.05	52.67	316.47	216.25	109.33
340	30.6	167.78	14.81	330.48	59.32	335.76	230.17	116.54
360	32.4	177.45	16.59	348.72	66.34	354.97	244.18	123.82
380	34.2	187.09	18.46	366.75	73.73	374.09	258.26	131.17
400	36.0	196.70	20.43	384.58	81.47	393.11	272.44	138.61

SPIRAL PARTS FOR 20° CURVE

L	*S*	*q*	*p*	*Y*	*X*	*C*	*U*	*V*
60	6.0°	29.84	0.52	59.93	2.09	59.97	40.02	20.02
80	8.0	39.77	0.92	79.85	3.72	79.93	53.39	26.7
100	10.0	49.70	1.43	99.70	5.81	99.87	66.77	33.4
120	12.0	59.61	2.06	119.48	8.35	119.77	80.19	40.1
140	14.0	69.51	2.80	139.17	11.35	139.63	93.63	46.
160	16.0	79.40	3.66	158.76	14.81	159.45	107.11	53.
180	18.0	89.26	4.63	178.24	18.72	179.22	120.63	60.
200	20.0	99.11	5.71	197.59	23.07	198.93	134.20	67.
220	22.0	108.93	6.90	216.80	27.87	218.58	147.82	74
240	24.0	118.73	8.20	235.85	33.10	238.16	161.51	81
260	26.0	128.50	9.62	254.73	38.76	257.66	175.25	8
280	28.0	138.24	11.15	273.42	44.85	277.08	189.07	9
300	30.0	147.95	12.78	291.92	51.36	296.41	202.97	10
320	32.0	157.63	14.52	310.21	58.28	315.64	216.95	1
340	34.0	167.27	16.38	328.28	65.60	334.77	231.02	1
360	36.0	176.87	18.34	346.12	73.33	353.80	245.19	1
	38.0	186.43	20.40	363.71	81.44	372.71	259.47	1
	40.0	195.95	22.57	381.04	89.94	391.51	273.86	1

TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
0.0°	1.00000	1.00000	.00000	.66667	.33333	.00000	.0000	.50000	.0000	0.0°
.1	1.00000	1.00000	.00058	.66667	.33333	.00015	.0000	.50000	.0001	.1
.2	1.00000	1.00000	.00116	.66667	.33333	.00029	.0000	.50000	.0003	.2
.3	1.00000	1.00000	.00175	.66667	.33333	.00044	.0000	.50000	.0004	.3
.4	1.00000	1.00000	.00233	.66667	.33333	.00058	.0000	.50000	.0005	.4
.5	1.00000	.99999	.00291	.66667	.33334	.00073	.0000	.50000	.0006	.5
.6	1.00000	.99999	.00349	.66667	.33334	.00087	.0000	.50000	.0008	.6
.7	.99999	.99999	.00407	.66667	.33334	.00102	.0000	.50000	.0009	.7
.8	.99999	.99998	.00465	.66667	.33334	.00116	.0000	.50000	.0010	.8
.9	.99999	.99998	.00524	.66668	.33334	.00131	.0000	.50000	.0011	.9
1.0	.99999	.99997	.00582	.66668	.33334	.00145	.0000	.49999	.0013	1.0
.1	.99998	.99996	.00640	.66668	.33335	.00160	.0000	.49999	.0014	.1
.2	.99998	.99996	.00698	.66668	.33335	.00175	.0000	.49999	.0015	.2
.3	.99998	.99995	.00756	.66668	.33335	.00189	.0000	.49999	.0017	.3
.4	.99997	.99994	.00814	.66669	.33335	.00204	.0000	.49999	.0018	.4
.5	.99997	.99993	.00873	.66669	.33336	.00218	.0000	.49999	.0019	.5
.6	.99997	.99992	.00931	.66669	.33336	.00233	.0000	.49999	.0020	.6
.7	.99996	.99991	.00989	.66670	.33336	.00247	.0000	.49999	.0022	.7
.8	.99996	.99990	.01047	.66670	.33337	.00262	.0000	.49998	.0023	.8
.9	.99995	.99989	.01105	.66671	.33337	.00276	.0000	.49998	.0024	.9
2.0	.99995	.99988	.01163	.66671	.33337	.00291	.0000	.49998	.0025	2.0
.1	.99994	.99987	.01222	.66671	.33338	.00305	.0000	.49998	.0027	.1
.2	.99994	.99985	.01280	.66672	.33338	.00320	.0000	.49998	.0028	.2
.3	.99993	.99984	.01338	.66672	.33338	.00335	.0001	.49997	.0029	.3
.4	.99992	.99983	.01396	.66673	.33339	.00349	.0001	.49997	.0031	.4
.5	.99992	.99981	.01454	.66673	.33339	.00364	.0001	.49997	.0032	.5
.6	.99991	.99980	.01512	.66674	.33340	.00378	.0001	.49997	.0033	.6
.7	.99990	.99978	.01571	.66674	.33340	.00393	.0001	.49996	.0034	.7
.8	.99990	.99977	.01629	.66675	.33341	.00407	.0001	.49996	.0036	.8
.9	.99989	.99975	.01687	.66676	.33342	.00422	.0001	.49996	.0037	.9
3.0	.99988	.99973	.01745	.66676	.33342	.00436	.0001	.49996	.0038	3.0
.1	.99987	.99971	.01803	.66677	.33343	.00451	.0001	.49995	.0039	.1
.2	.99986	.99969	.01861	.66678	.33343	.00465	.0001	.49995	.0041	.2
.3	.99985	.99967	.01919	.66678	.33344	.00480	.0001	.49995	.0042	.3
.4	.99985	.99965	.01978	.66679	.33345	.00494	.0001	.49994	.0043	.4
.5	.99984	.99963	.02036	.66680	.33345	.00509	.0001	.49994	.0045	.5
.6	.99983	.99961	.02094	.66681	.33346	.00524	.0001	.49994	.0046	.6
.7	.99982	.99959	.02152	.66681	.33347	.00538	.0001	.49993	.0047	.7
.8	.99981	.99956	.02210	.66682	.33347	.00553	.0002	.49993	.0048	.8
.9	.99980	.99954	.02268	.66683	.33348	.00567	.0002	.49993	.0050	.9
4.0	.99979	.99952	.02326	.66684	.33349	.00582	.0002	.49992	.0051	4.0
.1	.99978	.99949	.02384	.66685	.33350	.00596	.0002	.49992	.0052	.1
.2	.99976	.99947	.02443	.66686	.33351	.00611	.0002	.49991	.0053	.2
.3	.99975	.99944	.02501	.66686	.33351	.00625	.0002	.49991	.0055	.3
.4	.99974	.99941	.02559	.66687	.33352	.00640	.0002	.49991	.0056	.4
.5	.99973	.99939	.02617	.66688	.33353	.00654	.0002	.49990	.0057	.5
.6	.99972	.99936	.02675	.66689	.33354	.00669	.0002	.49990	.0059	.6
.7	.99970	.99933	.02733	.66690	.33355	.00683	.0002	.49989	.0060	.7
.8	.99969	.99930	.02791	.66691	.33356	.00698	.0003	.49989	.0061	.8
.9	.99968	.99927	.02849	.66692	.33357	.00713	.0003	.49988	.0062	.9
5.0	.99967	.99924	.02907	.66693	.33358	.00727	.0003	.49988	.0064	5.0
.1	.99965	.99921	.02965	.66695	.33359	.00742	.0003	.49987	.0065	.1
.2	.99964	.99918	.03023	.66696	.33360	.00756	.0003	.49987	.0066	.2
.3	.99962	.99915	.03082	.66697	.33361	.00771	.0003	.49986	.0067	.3
.4	.99961	.99912	.03140	.66698	.33362	.00785	.0003	.49986	.0069	.4
.5	.99960	.99908	.03198	.66699	.33363	.00800	.0003	.49985	.0070	.5
.6	.99958	.99905	.03256	.66700	.33364	.00814	.0003	.49985	.0071	.6
.7	.99957	.99902	.03314	.66702	.33365	.00829	.0004	.49984	.0073	.7
.8	.99955	.99898	.03372	.66703	.33366	.00843	.0004	.49984	.0074	.8
.9	.99953	.99895	.03430	.66704	.33367	.00858	.0004	.49983	.0075	.9

TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
6.0°	.99952	.99891	.03488	.66705	.33369	.00872	.0004	.49982	.0076	6.0°
.1	.99950	.99887	.03546	.66707	.33370	.00887	.0004	.49982	.0078	.1
.2	.99949	.99884	.03604	.66708	.33371	.00901	.0004	.49981	.0079	.2
.3	.99947	.99880	.03662	.66709	.33372	.00916	.0004	.49981	.0080	.3
.4	.99945	.99876	.03720	.66711	.33373	.00930	.0005	.49980	.0081	.4
.5	.99944	.99872	.03778	.66712	.33375	.00945	.0005	.49979	.0083	.5
.6	.99942	.99868	.03836	.66713	.33376	.00959	.0005	.49979	.0084	.6
.7	.99940	.99864	.03894	.66715	.33377	.00974	.0005	.49978	.0085	.7
.8	.99938	.99860	.03952	.66716	.33379	.00989	.0005	.49977	.0086	.8
.9	.99936	.99856	.04010	.66718	.33380	.01003	.0005	.49977	.0088	.9
7.0	.99935	.99852	.04068	.66719	.33381	.01018	.0005	.49976	.0089	7.0
.1	.99933	.99847	.04126	.66721	.33383	.01032	.0006	.49975	.0090	.1
.2	.99931	.99843	.04184	.66722	.33384	.01047	.0006	.49975	.0091	.2
.3	.99929	.99839	.04242	.66724	.33385	.01061	.0006	.49974	.0093	.3
.4	.99927	.99834	.04300	.66725	.33387	.01076	.0006	.49973	.0094	.4
.5	.99925	.99830	.04358	.66727	.33388	.01090	0006	.49972	.0095	.5
.6	.99923	.99825	.04416	.66729	.33390	.01105	.0006	.49972	.0097	.6
.7	.99921	.99821	.04474	.66730	.33391	.01119	.0007	.49971	.0098	.7
.8	.99919	.99816	.04532	.66732	.33393	.01134	.0007	.49970	.0099	.8
.9	.99917	.99811	.04590	.66734	.33394	.01148	.0007	.49969	.0100	.9
8.0	.99914	.99806	.04648	.66735	.33396	.01163	.0007	.49969	.0102	8.0
.1	.99912	.99801	.04706	.66737	.33398	.01177	.0007	.49968	.0103	.1
.2	.99910	.99797	.04764	.66739	.33399	.01192	.0007	.49967	.0104	.2
.3	.99908	.99792	.04822	.66741	.33401	.01206	.0008	.49966	.0105	.3
.4	.99906	.99786	.04880	.66742	.33402	.01221	.0008	.49965	.0107	.4
.5	.99903	.99781	.04937	.66744	.33404	.01235	.0008	.49965	.0108	.5
.6	.99901	.99776	.04995	.66746	.33406	.01250	.0008	.49964	.0109	.6
.7	.99899	.99771	.05053	.66748	.33407	.0126	.0008	.49963	.0110	.7
.8	.99897	.99766	.05111	.66750	.33409	.01279	.0009	.49962	.0112	.8
.9	.99894	.99760	.05169	.66752	.33411	.01293	.0009	.49961	.0113	.9
9.0	.99892	.99755	.05227	.66754	.33413	.01308	.0009	.49960	.0114	9.0
.1	.99889	.99749	.05285	.66756	.33414	.01322	.0009	.49959	.0116	.1
.2	.99887	.99744	.05342	.66758	.33416	.01337	.0009	.49959	.0117	.2
.3	.99884	.99738	.05400	.66760	.33418	.01351	.0010	.49958	.0118	.3
.4	.99882	.99733	.05458	.66762	.33420	.01366	.0010	.49957	.0119	.4
.5	.99879	.99727	.05516	.66764	.33422	.01381	.0010	.49956	.0120	.5
.6	.99877	.99721	.05574	.66766	.33424	.01395	.0010	.49955	.0122	.6
.7	.99874	.99715	.05632	.66768	.33425	.01410	.0010	.49954	.0123	.7
.8	.99872	.99709	.05690	.66770	.33427	.01424	.0011	.49953	.0124	.8
.9	.99869	.99704	.05747	.66772	.33429	.01439	.0011	.49952	.0126	.9
10.0	.99866	.99698	.05805	.66774	.33431	.01453	.0011	.49951	.0127	10.0
.1	.99864	.99691	.05863	.66776	.33433	.01468	.0011	.49950	.0128	.1
.2	.99861	.99685	.05921	.66779	.33435	.01482	.0012	.49949	.0129	.2
.3	.99858	.99679	.05979	.66781	.33437	.01497	.0012	.49948	.0131	.3
.4	.99856	.99673	.06036	.66783	.33439	.01511	.0012	.49947	.0132	.4
.5	.99853	.99667	.06094	.66785	.33441	.01526	.0012	.49946	.0133	.5
.6	.99850	.99660	.06152	.66787	.33443	.01540	.0012	.49945	.0134	.6
.7	.99847	.99654	.06210	.66790	.33446	.01555	.0013	.49944	.0136	.7
.8	.99844	.99647	.06267	.66792	.33448	.01569	.0013	.49943	.0137	.8
.9	.99841	.99641	.06325	.66794	.33450	.01584	.0013	.49942	.0138	.9
11.0	.99838	.99634	.06383	.66797	.33452	.01598	.0013	.49941	.0139	11.
.1	.99835	.99627	.06441	.66799	.33454	.01612	.0014	.49940	.0141	.
.2	.99832	.99621	.06498	.66802	.33456	.01627	.0014	.49939	.0142	.
.3	.99829	.99614	.06556	.66804	.33459	.01641	.0014	.49937	.0143	.
.4	.99826	.99607	.06614	.66806	.33461	.01656	.0014	.49936	.0144	
.5	.99823	.99600	.06671	.66809	.33463	.01670	.0015	.49935	.0146	
6	.99820	.99593	.06729	.66811	.33465	.01685	.0015	.49934	.0147	
.	.99817	.99586	.06787	.66814	.33468	.01699	.0015	.49933	.0148	
	.99814	.99579	.06844	.66816	.33470	.01714	.0015	.49932	.0149	
	.99811	.99572	.06902	.66819	.33472	.01728	.0016	.49931	.0151	

TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=cL-fD$		S
						a	b	c	f	
12.0°	.99808	.99565	.06960	.66822	.33475	.01743	.0016	.49929	.0152	12.0°
.1	.99804	.99557	.07017	.66824	.33477	.01757	.0016	.49928	.0153	.1
.2	.99801	.99550	.07075	.66827	.33479	.01772	.0016	.49927	.0154	.2
.3	.99798	.99543	.07133	.66830	.33482	.01786	.0017	.49926	.0156	.3
.4	.99795	.99535	.07190	.66832	.33484	.01801	.0017	.49925	.0157	.4
.5	.99791	.99528	.07248	.66835	.33487	.01815	.0017	.49923	.0158	.5
.6	.99788	.99520	.07305	.66838	.33489	.01830	.0018	.49922	.0159	.6
.7	.99785	.99513	.07363	.66840	.33492	.01844	.0018	.49921	.0160	.7
.8	.99781	.99505	.07421	.66843	.33494	.01859	.0018	.49920	.0162	.8
.9	.99778	.99497	.07478	.66846	.33497	.01873	.0018	.49918	.0163	.9
13.0	.99774	.99489	.07536	.66849	.33499	.01888	.0019	.49917	.0164	13.0
.1	.99771	.99481	.07593	.66852	.33502	.01902	.0019	.49916	.0165	.1
.2	.99767	.99474	.07651	.66854	.33504	.01917	.0019	.49915	.0167	.2
.3	.99764	.99466	.07708	.66857	.33507	.01931	.0020	.49913	.0168	.3
.4	.99760	.99457	.07766	.66860	.33510	.01946	.0020	.49912	.0169	.4
.5	.99757	.99449	.07823	.66863	.33512	.01960	.0020	.49911	.0170	.5
.6	.99753	.99441	.07881	.66866	.33515	.01974	.0020	.49909	.0172	.6
.7	.99749	.99433	.07938	.66869	.33518	.01989	.0021	.49908	.0173	.7
.8	.99746	.99425	.07996	.66872	.33520	.02003	.0021	.49907	.0174	.8
.9	.99742	.99416	.08053	.68875	.33523	.02018	.0021	.49905	.0175	.9
14.0	.99738	.99408	.08111	.66878	.33526	.02032	.0022	.49905	.0177	14.0
.1	.99735	.99399	.08168	.66881	.33529	.02047	.0022	.49903	.0178	.1
.2	.99731	.99391	.08226	.66884	.33531	.02061	.0022	.49901	.0179	.2
.3	.99727	.99382	.08283	.66887	.33534	.02076	.0023	.49900	.0180	.3
.4	.99723	.99374	.08340	.66890	.33537	.02090	.0023	.49898	.0182	.4
.5	.99719	.99365	.08398	.66893	.33540	.02105	.0023	.49897	.0183	.5
.6	.99715	.99356	.08455	.66897	.33543	.02119	.0024	.49896	.0184	.6
.7	.99711	.99347	.08513	.66900	.33546	.02134	.0024	.49894	.0185	.7
.8	.99708	.99339	.08570	.66903	.33549	.02148	.0024	.49893	.0186	.8
.9	.99704	.99330	.08627	.66906	.33552	.02162	.0025	.49891	.0188	.9
15.0	.99700	.99321	.08685	.66909	.33555	.02177	.0025	.49890	.0189	15.0
.1	.99696	.99312	.08742	.66913	.33558	.02191	.0025	.49888	.0190	.1
.2	.99692	.99302	.08799	.66916	.33561	.02206	.0026	.49887	.0191	.2
.3	.99687	.99293	.08857	.66919	.33464	.02220	.0026	.49885	.0193	.3
.4	.99683	.99284	.08914	.66923	.33567	.02235	.0026	.49884	.0194	.4
.5	.99679	.99275	.08971	.66926	.33570	.02249	.0026	.49882	.0195	.5
.6	.99675	.99265	.09028	.66929	.33573	.02264	.0027	.49881	.0196	.6
.7	.99671	.99256	.09086	.66933	.33576	.02278	.0027	.49879	.0198	.7
.8	.99667	.99246	.09143	.66936	.33579	.02292	.0028	.49878	.0199	.8
.9	.99662	.99237	.09200	.66940	.33582	.02307	.0028	.49876	.0200	.9
16.0	.99658	.99227	.09257	.66943	.33585	.02321	.0028	.49875	.0201	16.0
.1	.99654	.99218	.09315	.66947	.33588	.02336	.0029	.49873	.0202	.3
.2	.99650	.99208	.09372	.66950	.33592	.02350	.0029	.49872	.0204	.2
.3	.99645	.99198	.09429	.66954	.33595	.02365	.0029	.49870	.0205	.3
.4	.99641	.99188	.09486	.66957	.33598	.02379	.0030	.49868	.0206	.4
.5	.99637	.99178	.09543	.66961	.33601	.02393	.0030	.49867	.0207	.5
.6	.99632	.99169	.09600	.66964	.33605	.02408	.0030	.49865	.0209	.6
.7	.99628	.99159	.09658	.66968	.33608	.02422	.0031	.49863	.0210	.7
.8	.99623	.99148	.09715	.66972	.33611	.02437	.0031	.49862	.0211	.8
.9	.99619	.99138	.09772	.66975	.33615	.02451	.0032	.49860	.0212	.9
17.0	.99614	.99128	.09829	.66979	.33618	.02466	.0032	.49859	.0213	17.0
.1	.99610	.99118	.09886	.66983	.33621	.02480	.0032	.49857	.0215	.1
.2	.99605	.99108	.09943	.66986	.33625	.02494	.0033	.49855	.0216	.2
.3	.99600	.99097	.10000	.66990	.33628	.02509	.0033	.49853	.0217	.3
.4	.99596	.99087	.10057	.66994	.33632	.02523	.0033	.39852	.0218	.4
.5	.99591	.99076	.10114	.66998	.33635	.02538	.0034	.49850	.0220	.5
.6	.99587	.99066	.10171	.67002	.33639	.02552	.0034	.49848	.0221	.6
.7	.99582	.99055	.10228	.67005	.33642	.02567	.0035	.49847	.0222	.7
.8	.99577	.99044	.10285	.67009	.33646	.02581	.0035	.49845	.0223	.8
.9	.99572	.99034	.10342	.67013	.33649	.02595	.0035	.49843	.0224	.9

TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=cL-fD$		S
						a	b	c	f	
.0°	.99568	.99023	.10399	.67017	.33653	.02610	.0036	.49841	.0226	18.0°
.1	.99563	.99012	.10456	.67021	.33657	.02624	.0036	.49840	.0227	.1
.2	.99558	.99001	.10513	.67025	.33660	.02639	.0037	.49838	.0228	.2
.3	.99553	.98990	.10570	.67029	.33664	.02653	.0037	.49836	.0229	.3
.4	.99548	.98979	.10627	.67033	.33667	.02667	.0037	.49834	.0230	.4
.5	.99543	.98968	.10684	.67037	.33671	.02682	.0038	.49833	.0232	.5
.6	.99538	.98957	.10741	.67041	.33675	.02696	.0038	.49831	.0233	.6
.7	.99533	.98946	.10798	.67045	.33679	.02711	.0039	.49829	.0234	.7
.8	.99528	.98935	.10855	.67049	.33682	.02725	.0039	.49827	.0235	.8
.9	.99523	.98923	.10912	.67053	.33686	.02739	.0039	.49825	.0236	.9
19.0	.99518	.98912	.10968	.67058	.33690	.02754	.0040	.49823	.0238	19.0
.1	.99513	.98901	.11025	.67062	.33694	.02768	.0040	.49821	.0239	.1
.2	.99508	.98889	.11082	.67066	.33697	.02783	.0041	.49820	.0240	.2
.3	.99503	.98878	.11139	.67070	.33701	.02797	.0041	.49818	.0241	.3
.4	.99498	.98866	.11196	.67074	.33705	.02811	.0041	.49816	.0242	.4
.5	.99493	.98854	.11252	.67079	.33709	.02826	.0042	.49814	.0244	.5
.6	.99487	.98843	.11309	.67083	.33713	.02840	.0042	.49812	.0245	.6
.7	.99482	.98831	.11366	.67087	.33717	.02854	.0043	.49810	.0246	.7
.8	.99477	.98819	.11423	.67092	.33721	.02869	.0043	.49808	.0247	.8
.9	.99472	.98807	.11479	.67096	.33725	.02883	.0044	.49806	.0248	.9
20.0	.99466	.98795	.11536	.67100	.33729	.02898	.0044	.49804	.0250	20.0
.1	.99461	.98783	.11593	.67105	.33733	.02912	.0044	.49802	.0251	.1
.2	.99456	.98771	.11649	.67109	.33737	.02926	.0045	.49800	.0252	.2
.3	.99450	.98759	.11706	.67114	.33741	.02941	.0045	.49798	.0253	.3
.4	.99445	.98747	.11763	.67118	.33745	.02955	.0046	.49796	.0254	.4
.5	.99439	.98734	.11819	.67123	.33749	.02969	.0046	.49794	.0256	.5
.6	.99434	.98722	.11876	.67127	.33753	.02984	.0047	.49792	.0257	.6
.7	.99428	.98710	.11932	.67132	.33757	.02998	.0047	.49790	.0258	.7
.8	.99423	.98697	.11989	.67136	.33762	.03013	.0048	.49788	.0259	.8
.9	.99417	.98685	.12046	.67141	.33766	.03027	.0048	.49786	.0260	.9
21.0	.99412	.98672	.12102	.67145	.33770	.03041	.0048	.49784	.0262	21.0
.1	.99406	.98660	.12159	.67150	.33774	.03056	.0049	.49782	.0263	.1
.2	.99400	.98647	.12215	.67155	.33778	.03070	.0049	.49780	.0264	.2
.3	.99395	.98634	.12272	.67159	.33783	.03084	.0050	.49778	.0265	.3
.4	.99389	.98622	.12328	.67164	.33787	.03099	.0050	.49776	.0266	.4
.5	.99383	.98609	.12385	.67169	.33791	.03113	.0051	.49774	.0267	.5
.6	.99378	.98596	.12441	.67173	.33796	.03127	.0051	.49772	.0268	.6
.7	.99372	.98583	.12497	.67178	.33800	.03142	.0052	.49770	.0270	.7
.8	.99366	.98570	.12554	.67183	.33804	.03156	.0052	.49768	.0271	.8
.9	.99360	.98557	.12610	.67188	.33809	.03170	.0053	.49765	.0272	.9
22.0	.99354	.98544	.12667	.67193	.33813	.03185	.0053	.49763	.0273	22.0
.1	.99349	.98531	.12723	.67197	.33818	.03199	.0054	.49761	.0275	.1
.2	.99343	.98517	.12779	.67202	.33822	.03213	.0054	.49759	.0276	.2
.3	.99337	.98504	.12836	.67207	.33827	.03228	.0055	.49757	.0277	.3
.4	.99331	.98491	.12892	.67212	.33831	.03242	.0055	.49755	.0278	.4
.5	.99325	.98477	.12948	.67217	.33836	.03256	.0056	.49752	.0279	.5
.6	.99319	.98464	.13005	.67222	.33840	.03271	.0056	.49750	.0281	.6
.7	.99313	.98450	.13061	.67227	.33845	.03285	.0057	.49748	.0282	.7
.8	.99307	.98437	.13117	.67232	.33849	.03299	.0057	.49746	.0283	.8
.9	.99301	.98423	.13173	.67237	.33854	.03314	.0058	.49744	.0284	.9
23.0	.99295	.98409	.13230	.67242	.33859	.03328	.0058	.49741	.0285	23.
.1	.99288	.98396	.13286	.67247	.33863	.03342	.0059	.49739	.0286	
.2	.99282	.98382	.13342	.67252	.33868	.03357	.0059	.49737	.0288	
.3	.99276	.98368	.13398	.67258	.33873	.03371	.0060	.49735	.0289	
.4	.99270	.98354	.13454	.67263	.33877	.03385	.0060	.49732	.0290	
5	.99264	.98340	.13510	.67268	.33882	.03400	.0061	.49730	.0291	
6	.99257	.98326	.13567	.67273	.33887	.03414	.0061	.49728	.0292	
7	.99251	.98312	.13623	.67278	.33892	.03428	.0062	.49725	.0293	
8	.99245	.98298	.13679	.67284	.33896	.03443	.0062	.49723	.0295	
9	.99238	.98283	.13735	.67289	.33901	.03457	.0063	.49721	.0296	

TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
24.0°	.99232	.98269	.13791	.67294	.33906	.03471	.0063	.49718	.0297	24.0°
.1	.99226	.98255	.13847	.67300	.33911	.03485	.0064	.49716	.0298	.1
.2	.99219	.98240	.13903	.67305	.33916	.03500	.0064	.49714	.0299	.2
.3	.99213	.98226	.13959	.67310	.33921	.03514	.0065	.49711	.0300	.3
.4	.99206	.98211	.14015	.67316	.33926	.03528	.0065	.49709	.0302	.4
.5	.99200	.98197	.14071	.67321	.33931	.03543	.0066	.49707	.0303	.5
.6	.99193	.98182	.14127	.67327	.33936	.03557	.0066	.49704	.0304	.6
.7	.99187	.98167	.14183	.67332	.33941	.03571	.0067	.49702	.0305	.7
.8	.99180	.98153	.14239	.67338	.33946	.03585	.0067	.49699	.0306	.8
.9	.99174	.98138	.14295	.67343	.33951	.03600	.0068	.49697	.0307	.9
25.0	.99167	.98123	.14350	.67349	.33956	.03614	.0068	.49695	.0309	25.0
.1	.99160	.98108	.14406	.67354	.33961	.03628	.0069	.49692	.0310	.1
.2	.99154	.98093	.14462	.67360	.33966	.03643	.0069	.49690	.0311	.2
.3	.99147	.98078	.14518	.67365	.33971	.03657	.0070	.49687	.0312	.3
.4	.99140	.98063	.14574	.67371	.33976	.03671	.0071	.49685	.0313	.4
.5	.99133	.98048	.14629	.67377	.33981	.03685	.0071	.49682	.0314	.5
.6	.99127	.98033	.14685	.67382	.33987	.03700	.0072	.49680	.0315	.6
.7	.99120	.98017	.14741	.67388	.33992	.03714	.0072	.49677	.0317	.7
.8	.99113	.98002	.14797	.67394	.33997	.03728	.0073	.49675	.0318	.8
.9	.99106	.97987	.14852	.67400	.34002	.03742	.0073	.49672	.0319	.9
26.0	.99099	.97971	.14908	.67405	.34008	.03757	.0074	.49670	.0320	26.0
.1	.99092	.97956	.14964	.67411	.34013	.03771	.0074	.49667	.0321	.1
.2	.99085	.97940	.15019	.67417	.34018	.03785	.0075	.49665	.0322	.2
.3	.99078	.97925	.15075	.67423	.34024	.03800	.0076	.49662	.0323	.3
.4	.99071	.97909	.15131	.67429	.34029	.03814	.0076	.49660	.0325	.4
.5	.99064	.97893	.15186	.67435	.34035	.03828	.0077	.49657	.0326	.5
.6	.99057	.97878	.15242	.67441	.34040	.03842	.0077	.49654	.0327	.6
.7	.99050	.97862	.15297	.67447	.34045	.03857	.0078	.49652	.0328	.7
.8	.99043	.97846	.15353	.67452	.34051	.03871	.0078	.49649	.0329	.8
.9	.99036	.97830	.15408	.67458	.34056	.03885	.0079	.49647	.0330	.9
27.0	.99029	.97814	.15464	.67465	.34062	.03899	.0080	.49644	.0331	27.0
.1	.99022	.97798	.15519	.67471	.34067	.03913	.0080	.49641	.0333	.1
.2	.99014	.97782	.15575	.67477	.34073	.03928	.0081	.49639	.0334	.2
.3	.99007	.97766	.15630	.67483	.34079	.03942	.0081	.49636	.0335	.3
.4	.99000	.97749	.15686	.67489	.34084	.03956	.0082	.49633	.0336	.4
.5	.98993	.97733	.15741	.67495	.34090	.03970	.0082	.49631	.0337	.5
.6	.98985	.97717	.15796	.67501	.34095	.03985	.0083	.48628	.0338	.6
.7	.98978	.97700	.15852	.67507	.34101	.03999	.0084	.49625	.0339	.7
.8	.98971	.97684	.15907	.67514	.34107	.04013	.0084	.49623	.0340	.8
.9	.98963	.97667	.15962	.67520	.34113	.04027	.0085	.49620	.0342	.9
28.0	.98956	.97651	.16018	.67526	.34118	.04041	.0085	.49617	.0343	28.0
.1	.98948	.97634	.16073	.67532	.34124	.04056	.0086	.49615	.0344	.1
.2	.98941	.97617	.16128	.67539	.34130	.04070	.0087	.49612	.0345	.2
.3	.98933	.97601	.16183	.67545	.34136	.04084	.0087	.49609	.0346	.3
.4	.98926	.97584	.16239	.67551	.34141	.04098	.0088	.49606	.0347	.4
.5	.98918	.97567	.16294	.67558	.34147	.04113	.0088	.49604	.0348	.5
.6	.98911	.97550	.16349	.67564	.34153	.04127	.0089	.49601	.0349	.6
.7	.98903	.97533	.16404	.67571	.34159	.04151	.0090	.49598	.0351	.7
.8	.98895	.97516	.16459	.67577	.34165	.04155	.0090	.49595	.0352	.8
.9	.98888	.97499	.16514	.67584	.34171	.04169	.0091	.49592	.0353	.9
29.0	.98880	.97482	.16569	.67590	.34177	.04184	.0092	.49590	.0354	29.0
.1	.98872	.97465	.16624	.67597	.34183	.04198	.0092	.49587	.0355	.1
.2	.98865	.97447	.16679	.67603	.34189	.04212	.0093	.49584	.0356	.2
.3	.98857	.97430	.16734	.67610	.34195	.04226	.0093	.49581	.0357	.3
.4	.98849	.97413	.16789	.67616	.34201	.04240	.0094	.49578	.0358	.4
.5	.98841	.97395	.16844	.67623	.34207	.04254	.0095	.49575	.0359	.5
.6	.98833	.97378	.16899	.67630	.34213	.04269	.0095	.49573	.0361	.6
.7	.98826	.97360	.16954	.67636	.34219	.04283	.0096	.49570	.0362	.7
.8	.98818	.97343	.17009	.67643	.34225	.04297	.0097	.49567	.0363	.8
.9	.98810	.97325	.17064	.67650	.34232	.04311	.0097	.49564	.0364	.9

TABLE XLIX.—FUNCTIONS OF THE TEN-CHOR
SPIRAL

δ	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		δ
						a	b	e	f	
30 0°	.98802	.97307	.17119	.67657	.34238	.04325	.0098	.49561	.0365	30.
.1	.98794	.97290	.17174	.67663	.34244	.04339	.0098	.49558	.0366	
.2	.98786	.97272	.17229	.67670	.34250	.04354	.0099	.49555	.0367	
.3	.98778	.97254	.17283	.67677	.34257	.04368	.0100	.49552	.0368	
.4	.98770	.97236	.17338	.67684	.34263	.04382	.0100	.49549	.0369	
.5	.98762	.97218	.17393	.67691	.34269	.04396	.0101	.49546	.0371	
.6	.98754	.97200	.17448	.67698	.34276	.04410	.0102	.49543	.0372	
.7	.98745	.97182	.17502	.67705	.34282	.04424	.0102	.49540	.0373	
.8	.98737	.97164	.17557	.67712	.34288	.04439	.0103	.49537	.0374	
.9	.98729	.97146	.17612	.67719	.34295	.04453	.0104	.49534	.0375	
31.0	.98721	.97127	.17666	.67726	.34301	.04467	.0104	.49531	.0376	31.
.1	.98713	.97109	.17721	.67733	.34308	.04481	.0105	.49528	.0377	
.2	.98704	.97091	.17776	.67740	.34314	.04495	.0106	.49525	.0378	
.3	.98696	.97072	.17830	.67747	.34321	.04509	.0106	.49522	.0379	
.4	.98688	.97054	.17885	.67754	.34327	.04523	.0107	.49519	.0380	
.5	.98680	.97035	.17939	.67761	.34334	.04538	.0108	.49516	.0381	
.6	.98671	.97017	.17994	.67768	.34340	.04552	.0108	.49513	.0383	
.7	.98663	.96998	.18048	.67775	.34347	.04566	.0109	.49510	.0384	
.8	.98654	.96979	.18103	.67783	.34353	.04580	.0110	.49507	.0385	
.9	.98646	.96960	.18157	.67790	.34360	.04594	.0110	.49504	.0386	
32.0	.98637	.96942	.18212	.67797	.34367	.04608	.0111	.49501	.0387	32.
.1	.98629	.96923	.18266	.67804	.34373	.04622	.0112	.49498	.0388	
.2	.98620	.96904	.18320	.67812	.34380	.04636	.0112	.49495	.0389	
.3	.98612	.96885	.18375	.67819	.34387	.04650	.0113	.49491	.0390	
.4	.98603	.96866	.18429	.67826	.34394	.04665	.0114	.49488	.0391	
.5	.98595	.96847	.18483	.67834	.34400	.04679	.0114	.49485	.0392	
.6	.98586	.96827	.18538	.67841	.34407	.04693	.0115	.49482	.0393	
.7	.98577	.96808	.18592	.67849	.34414	.04707	.0116	.49479	.0394	
.8	.98569	.96789	.18646	.67856	.34421	.04721	.0116	.49476	.0395	
.9	.98560	.96770	.18700	.67864	.34428	.04735	.0117	.49473	.0397	
33.0	.98551	.96750	.18754	.67871	.34435	.04749	.0118	.49469	.0398	33.
.1	.98543	.96731	.18809	.67879	.34442	.04763	.0118	.49466	.0399	
.2	.98534	.96712	.18863	.67886	.34448	.04777	.0119	.49463	.0400	
.3	.98525	.96692	.18917	.67894	.34455	.04791	.0120	.49460	.0401	
.4	.98516	.96672	.18971	.67901	.34462	.04805	.0121	.49457	.0402	
.5	.98507	.96653	.19025	.67909	.34469	.04820	.0121	.49453	.0403	
.6	.98499	.96633	.19079	.67917	.34477	.04834	.0122	.49450	.0404	
.7	.98490	.96613	.19133	.67925	.34484	.04848	.0123	.49447	.0405	
.8	.98481	.96593	.19187	.67932	.34491	.04862	.0123	.49443	.0406	
.9	.98472	.96574	.19241	.67940	.34498	.04876	.0124	.49440	.0407	
34.0	.98463	.96554	.19295	.67948	.34505	.04890	.0125	.49437	.0408	
.1	.98454	.96534	.19349	.67956	.34512	.04904	.0126	.49434	.0409	
.2	.98445	.96514	.19403	.67963	.34519	.04918	.0126	.49430	.0410	
.3	.98436	.96494	.19457	.67971	.34527	.04932	.0127	.49427	.0411	
.4	.98427	.96473	.19510	.67979	.34534	.04946	.0128	.49424	.0412	
.5	.98417	.96453	.19564	.67987	.34541	.04960	.0128	.49420	.0413	
.6	.98408	.96433	.19618	.67995	.34548	.04974	.0129	.49417	.041	
.7	.98399	.96413	.19672	.68003	.34556	.04988	.0130	.49414	.041	
.8	.98390	.96392	.19726	.68011	.34563	.05002	.0131	.49410	.041	
.9	.98381	.96372	.19779	.68019	.34570	.05016	.0131	.49407	.041	
35.0	.98371	.96351	.19833	.68027	.34578	.05030	.0132	.49404	.04	
.1	.98362	.96331	.19887	.68035	.34585	.05044	.0133	.49400	.04	
.2	.98353	.96310	.19940	.68043	.34593	.05058	.0133	.49397	.0	
.3	.98344	.96290	.19994	.68051	.34600	.05072	.0134	.49393	.0	
.4	.98334	.96269	.20047	.68059	.34608	.05086	.0135	.49390	.	
.5	.98325	.96248	.20101	.68068	.34615	.05100	.0136	.49387	.	
.6	.98315	.96227	.20155	.68076	.34623	.05115	.0136	.49383	.	
.7	.98306	.96207	.20208	.68084	.34630	.05129	.0137	.49380		
.8	.98297	.96186	.20262	.68092	.34638	.05143	.0138	.49376		
	[illegible]	.96165	.20315	.68101	.34645	.05157	.0139	.49373		

S	C/L	Y/L	X/L	U/L	V/L	p=aL−bD		q=eL−fD		S
						a	b	e	f	
36.0°	.98278	.96144	.20368	.68109	.34653	.05171	.0139	.49369	.0429	36.0°
.1	.98268	.96123	.20422	.68117	.34661	.05185	.0140	.49366	.0430	.1
.2	.98259	.96102	.20475	.68126	.34668	.05190	.0141	.49362	.0431	.2
.3	.98249	.96080	.20529	.68134	.34676	.05213	.0142	.49359	.0432	.3
.4	.98239	.96059	.20582	.68142	.34684	.05227	.0142	.49355	.0433	.4
.5	.98230	.96038	.20635	.68151	.34692	.05241	.0143	.49352	.0434	.5
.6	.98220	.96017	.20689	.68159	.34699	.05255	.0144	.49348	.0435	.6
.7	.98210	.95995	.20742	.68168	.34707	.05269	.0145	.49345	.0436	.7
.8	.98201	.95974	.20795	.68176	.34715	.05282	.0145	.49341	.0437	.8
.9	.98191	.95952	.20848	.68185	.34723	.05296	.0146	.49338	.0438	.9
37.0	.98181	.95931	.20901	.68194	.34731	.05310	.0147	.49334	.0439	37.0
.1	.98171	.95909	.20955	.68202	.34739	.05324	.0148	.49331	.0440	.1
.2	.98162	.95887	.21008	.68211	.34747	.05338	.0149	.49327	.0441	.2
.3	.98152	.95866	.21061	.68219	.34754	.05352	.0149	.49323	.0442	.3
.4	.98142	.95844	.21114	.68228	.34762	.05366	.0150	.49320	.0443	.4
.5	.98132	.95822	.21167	.68237	.34770	.05380	.0151	.49316	.0444	.5
.6	.98122	.95800	.21220	.68246	.34779	.05394	.0152	.49312	.0445	.6
.7	.98112	.95778	.21273	.68254	.34787	.05408	.0152	.49309	.0446	.7
.8	.98102	.95756	.21326	.68263	.34795	.05422	.0153	.49305	.0447	.8
.9	.98092	.95734	.21379	.68272	.34803	.05436	.0154	.49302	.0448	.9
38.0	.98082	.95712	.21432	.68281	.34811	.05450	.0155	.49298	.0449	38.0
.1	.98072	.95690	.21485	.68290	.34819	.05464	.0156	.49294	.0450	.1
.2	.98062	.95668	.21537	.68299	.34827	.05478	.0156	.49291	.0451	.2
.3	.98052	.95646	.21590	.68307	.34835	.05492	.0157	.49287	.0452	.3
.4	.98042	.95623	.21643	.68316	.34844	.05506	.0158	.49283	.0453	.4
.5	.98032	.95601	.21696	.68325	.34852	.05520	.0159	.49279	.0454	.5
.6	.98022	.95578	.21749	.68334	.34860	.05534	.0159	.49276	.0455	.6
.7	.98011	.95556	.21801	.68343	.34869	.05548	.0160	.49272	.0456	.7
.8	.98001	.95533	.21854	.68353	.34877	.05561	.0161	.49268	.0457	.8
.9	.97991	.95511	.21907	.68362	.34885	.05575	.0162	.49265	.0458	.9
39.0	.97981	.95488	.21959	.68371	.33894	.05589	.0163	.49261	.0459	39.0
.1	.97970	.95466	.22012	.68380	.34902	.05603	.0163	.49257	.0460	.1
.2	.97960	.95443	.22065	.68389	.34911	.05617	.0164	.49253	.0461	.2
.3	.97950	.95420	.22117	.68398	.34919	.05631	.0165	.49250	.0462	.3
.4	.97939	.95397	.22170	.68408	.34928	.05645	.0166	.49246	.0463	.4
.5	.97929	.95374	.22222	.68417	.34936	.05659	.0167	.49242	.0464	.5
.6	.97919	.95351	.22275	.68426	.34945	.05673	.0168	.49238	.0465	.6
.7	.97908	.95328	.22327	.68435	.34953	.05687	.0168	.49234	.0466	.7
.8	.97898	.95305	.22379	.68445	.34962	.05701	.0169	.49231	.0467	.8
.9	.97887	.95282	.95432	.68454	.34970	.05714	.0170	.49227	.0468	.9
40.0	.97877	.95259	.22484	.68464	.34979	.05728	.0171	.49223	.0469	40.0
.1	.97866	.95236	.22536	.68473	.34988	.05742	.0172	.49219	.0470	.1
.2	.97855	.95213	.22589	.68483	.34997	.05756	.0172	.49215	.0471	.2
.3	.97845	.95189	.22641	.68492	.35005	.05770	.0173	.49211	.0472	.3
.4	.97834	.95166	.22694	.68502	.35014	.05784	.0174	.49207	.0473	.4
.5	.97824	.95143	.22746	.68511	.35023	.05798	.0175	.49204	.0474	.5
.6	.97813	.95119	.22798	.68521	.35032	.05812	.0176	.49200	.0475	.6
.7	.97802	.95096	.22850	.68530	.35040	.05825	.0177	.49196	.0476	.7
.8	.97791	.95072	.22902	.68540	.35049	.05839	.0177	.49192	.0477	.8
.9	.97781	.95048	.22954	.68550	.35058	.05853	.0178	.49188	.0478	.9
41.0	.97770	.95025	.23006	.68559	.35067	.05867	.0179	.49184	.0479	41.0
.1	.97759	.95001	.23058	.68569	.35076	.05881	.0180	.49180	.0480	.1
.2	.97748	.94977	.23110	.68579	.35085	.05895	.0181	.49176	.0481	.2
.3	.97737	.94953	.23162	.68588	.35094	.05909	.0182	.49172	.0482	.3
.4	.97727	.94929	.23214	.68598	.35103	.05922	.0182	.49168	.0483	.4
.5	.97716	.94906	.23266	.68608	.35112	.05936	.0183	.49164	.0484	.5
.6	.97705	.94882	.23318	.68618	.35121	.05950	.0184	.49160	.0485	.6
.7	.97694	.94857	.23370	.68628	.35130	.05964	.0185	.49156	.0586	.7
.8	.97683	.94833	.23422	.68638	.35139	.05978	.0186	.49152	.0487	.8
.9	.97672	.94809	.23473	.68648	.35149	.05992	.0187	.49148	.0488	

TABLE XLIX.—FUNCTIONS OF THE TEN-CHORD SPIRAL

S	$\frac{C}{L}$	$\frac{Y}{L}$	$\frac{X}{L}$	$\frac{U}{L}$	$\frac{V}{L}$	$p=aL-bD$		$q=eL-fD$		S
						a	b	e	f	
42.0°	.97661	.94785	.23525	.68658	.35158	.06005	.0187	.49144	.0488	42.0°
.1	.97650	.94761	.23577	.68668	.35167	.06019	.0188	.49140	.0489	.1
.2	.97639	.94736	.23629	.68678	.35176	.06033	.0189	.49136	.0490	.2
.3	.97628	.94712	.23680	.68688	.35186	.06047	.0190	.49132	.0491	.3
.4	.97616	.94688	.23732	.68698	.37195	.06061	.0191	.49128	.0492	.4
.5	.97605	.94663	.23784	.68708	.35204	.06074	.0192	.49124	.0493	.5
.6	.97594	.94639	.23835	.68718	.35214	.06088	.0193	.49120	.0494	.6
.7	.97583	.94614	.23887	.68728	.35223	.06102	.0193	.49116	.0495	.7
.8	.97572	.94590	.23938	.68738	.35232	.06116	.0194	.48112	.0496	.8
.9	.97560	.94565	.23990	.68749	.35242	.06130	.0195	.49108	.0497	.9
43.0	.97549	.94540	.24041	.68759	.35251	.06143	.0196	.49103	.0498	43.0
.1	.97538	.94515	.24093	.68769	.35261	.06157	.0197	.49099	.0499	.1
.2	.97526	.94491	.24144	.68780	.35270	.06171	.0198	.49095	.0500	.2
.3	.97515	.94466	.24196	.68790	.35280	.06185	.0199	.49091	.0501	.3
.4	.97504	.94441	.24247	.68800	.35289	.06198	.0200	.49087	.0502	.4
.5	.97492	.94416	.24298	.68811	.35299	.06212	.0200	.49083	.0503	.5
.6	.97481	.94391	.24349	.68821	.35309	.06226	.0201	.49079	.0503	.6
.7	.97469	.94366	.24401	.68832	.35318	.06240	.0202	.49074	.0504	.7
.8	.97458	.94340	.24452	.68842	.35328	.06253	.0203	.49070	.0505	.8
.9	.97446	.94315	.24503	.68853	.35338	.06267	.0204	.49066	.0506	.9
44.0	.97435	.94290	.24554	.68863	.35347	.06281	.0205	.49062	.0507	44.0
.1	.97423	.94265	.24606	.68874	.35357	.06295	.0206	.49058	.0508	.1
.2	.97412	.94239	.24657	.68884	.35367	.06308	.0207	.49053	.0509	.2
.3	.97400	.94214	.24708	.68895	.35377	.06322	.0208	.49049	.0510	.3
.4	.97388	.94189	.24759	.68906	.35387	.06336	.0208	.49045	.0511	.4
.5	.97377	.94163	.24810	.68917	.35397	.06350	.0209	.49041	.0512	.5
.6	.97365	.94138	.24861	.68927	.35407	.06363	.0210	.49036	.0513	.6
.7	.97353	.94112	.24912	.68938	.35416	.06377	.0211	.49032	.0514	.7
.8	.97342	.94086	.24963	.68949	.35426	.06391	.0212	.49028	.0514	.8
.9	.97330	.94061	.25014	.68960	.35436	.06405	.0213	.49024	.0515	.9
45.0	.97318	.94035	.25064	.68971	.35446	.06418	.0214	.49019	.0516	45.0

EXPLANATION OF TABLES

Table I.—Contains the radius, and its logarithm, for every degree of curve to single minutes up to 10°, and thence by larger intervals up to 50°. With the radius is given also the perpendicular offset, t, from the tangent to a point on the curve at the end of the first 100-foot chord from the tangent-point, and the middle ordinate, m, of a 100-foot chord. See eqs. (16, 34, 37, 40 and 369).

Table II.—Contains the corrections to be added to the tangents and externals of any railroad curve, as obtained by reference to Table III, according to the degree of the given curve (found at head of columns), and its central angle, (found in the first column). If the given degree of curve, or central angle, does not appear in the table, the exact value of the correction may be easily obtained by interpolation.

Table III.—Contains the exact values of the tangents, **T**, and externals, **E**, to a 1° curve, for every 10′ of central angle, from 1° to 120° 50′. Approximate values of the tangent and external to any other degree of curve may be had by simply dividing the tabular values opposite the given central angle by the given degree of curve, expressed in degrees. These approximations may be made exact by adding the proper corrections taken from Table II. See eqs. (21) and (24).

Table IV.—Contains the value of Long Chords of from 2 to 12 stations, for every 10′ of degree of curve from 0° to 15°, and of a less number of stations for degrees of curve between 15° and 30°. As the chord of 1 station is always 100 feet, the column of the first station gives instead the *length of arc* subtended by the chord of 100 feet. See §§ 121, 122, 123, 124, 125 of the text.

Table V.—Contains the chords of a series of angles varying by half degrees up to 30° for radii varying by 100

feet up to 1000 feet. It shows, therefore, the linear opening between the extremities of two equal lines at any given number of hundred feet from their intersection, when the angle does not exceed 30°. For any distance exceeding 1000 we have only to add to the value found in that column the value found in the column headed by the excess of distance over 1000 feet. *Conversely*, the table gives the angular deflection required between two equal lines, in order that at a given distance from the point of intersection they may be separated a given amount.

TABLE VI.—Contains the values of Middle-Ordinates to long chords of from 2 to 12 stations, for every 10′ of degree of curve from 0° to 10°, and of from 2 to 6 stations for every curve from 10° to 20°, at 10-minute intervals. The table may be used, not only to fix the middle point of an arc, but also, in conjunction with the table of long chords, to locate intermediate stations. See §§ 121, 122, 123, 124, 125 of the text.

TABLE VII.—1. Contains values of the ratio $u = \frac{i_1}{\Delta}$ according to the notation of § 147 for finding the angle i (Fig. 34) between the radius PO of the curve at any point P, and the tangent PK to the valvoid arc PX by the simple formula eq. (80) $i = u\Delta$. The table embraces lengths of curve from 300 to 2000 feet, and central angles from 10° to 120°.

When $\frac{L\Delta}{1000} = 60°$, $u = \frac{1}{3}$, and for hasty approximation this value of u may be assumed in any case without consulting the table.

2. Contains values of the ratio $v = \frac{r}{L}$ for finding tl radius of the valvoid arc at the point P (Fig. 35) in ter of the length of curve $L = AP$ by the simple formula, (82), $r = vL$.

3. Contains values of the length l_1 of a valvoid arc lim by two curves of equal length laid out from the same gent and same P.C., but whose central angles differ b The length L of each curve is given in the first column he half sum of their central angles $\left(\frac{\Delta' + \Delta''}{2}\right)$ is give of the other columns.

When the central angles of two curves of equal length differ by x degrees the length l of the valvoid arc joining their extremities is expressed by the simple formula, Fig. 36, eq. (86)

$$l = P'P'' = (\Delta' - \Delta'')l_1$$

in which l_1 is taken from the column headed by $\frac{\Delta' + \Delta''}{2}$ and opposite the given value of L; or l_1 is found by interpolation if necessary. See § 150 and example.

Table VIII.—Contains the middle-ordinates of chords varying in length from 16 to 60 feet, and for degrees of curve varying from 1° to 50°. The use of the table is obvious. See § 315.

Table IX.—Gives the proper difference in elevation of rails on curves of various degrees from 1° to 50° for velocities varying from 10 to 60 miles per hour. See § 323.

Table X.—Contains the values of inches and fractions expressed in decimals of a foot for every 32d of an inch up to 1 foot.

Table XI.—Contains the radius and its logarithm for the metric curve based on a chord of 20 meters, the deflection angle ranging from 0° 10′ to 10°. It gives also the middle ordinate and tangent offset in meters for one chord, and the degree of curve of the identical curve if laid out in chords of 100 feet by the American method. Numerical values in this table can be derived from Table I by first doubling the deflection angle to get D and then multiplying the values in that table opposite D by 0.20.

Table XII.—Contains the acreage for right of way 100 feet wide given to tenths of a station or for 10 feet. The values for shorter lengths can be found by interpolating; those for different widths by proportion.

Table XIII.—Contains the vertical heights through which a train moving at certain velocities would be raised by its own momentum. The table is based on the formula $H = 0.0355V^2$ which includes the effect of the rotative energy of the wheels.

Table XIV.—Gives the rise of grades in feet per mile and their angle of inclination corresponding to a rise per station (100 feet) varying from 0.01 foot to 10 feet.

Table XV.—Contains values of the formula $(\log h - 1)$ 60384.3 in which h = reading of the barometer in inches. The inches and tenths of the readings are in the left-hand column, while the hundredths are found at the top of the other columns. The *difference* of any two values corresponding to two readings taken simultaneously at any two stations is the difference in elevation in feet of those stations. But the difference in height so found is subject to a correction for temperature given in the next table. See § 10.

Table XVI.—Contains coefficients of correction for atmospheric temperature, by which the approximate heights obtained by Table XV are to be multiplied for a correction of these heights, which correction is to be added or subtracted according as the coefficient given in the table is marked + or −. See § 11.

Table XVII.—Contains corrections in feet, required by the curvature of the earth and the refraction of the atmosphere, to be applied to the elevation of a distant object as obtained by a level or transit observation for distances ranging from 300 feet to 10 miles. See § 247.

Table XVIII.—Contains information for finding the differences in elevation and the horizontal distances in stadia work. The table is based on the formulas: the difference in elevation = $\frac{1}{2}ks \sin 2a + (f + c) \sin a$; and the horizontal distance = $ks^2 \cos a + (f + c) \cos a$.

The quantities in the table under "Diff. Elev." are values of $\frac{1}{2}ks \sin 2a$ where $k = 100$, $s = 1$ and a = the particular vertical angle. With any other values of k and s the product is found by use of the slide rule. The quantities at the foot of the column are values of $(f + c) \sin a$ for three values of $f + c$ (called c in the table). The products for other values of $(f + c)$ are found by interpolating.

Under "Correction to Horizontal Distances" are give $100 - ks \cos^2 a$ for different values of a, when $k = 100$ ar $s = 1$. Proper multiplication is made for other values these quantities.

ample.—Angle 2° 46′; rod reading 2.64; $f + c = 1$ $= 100$.

in elevation $= 4.82 \times 2.64 + .04 = 12.76$

Correction to horizontal distance for 100 feet = .23 and for a rod reading of 2.64 it is 2.64 × .23 or .6. Correction for $(f + c) \cos a$ is 1.1. Therefore the horizontal distance $264 - 0.6 + 1.1 = 264.5$.

TABLE XIX.—Contains the value of the sun's refraction in terms of the latitude of the place and the hour of the observation. The hour angle indicates the distance of the sun from the meridian. Three hours indicates either 9 A.M. or 3 P.M. These times are strictly *apparent solar time* which is governed by the motion of the *real sun.* For all practical purposes, however, the time may be considered *standard time* which is kept by the observer's watch.

Complete directions are given in the Nautical Almanac for the computation of declination, and the refraction values are applied to the declinations thus found. North declinations are + and those south are −. The refraction correction is to be added to the former and subtracted from the latter.

This table is used in laying off the proper declination for an observation with the solar attachment.

TABLE XX.—Gives the lengths of circular arcs to a radius = 1.

To find the length of any arc expressed in degrees, minutes, and seconds, take from the table the lengths of the given number of degrees, minutes, and seconds, respectively, and multiply their sum by the length of the radius. The product is the length of arc required.

TABLE XXI.—Contains the values of minutes and seconds expressed in decimals of a degree, for every 10″ of arc, and also for quarter minutes up to 1°.

TABLE XXII.—Contains the measurements necessary to lay down a turnout with frogs of given numbers or angles for both a standard and a 3-foot gauge. The distance BF is measured on the rail of the given track from the *heel* of the switch to the *point* of the frog, while af is the chord of the center line of the turnout between the same points. The radius r applies to the center line of the turnout. The distance aF'' is measured on the center line of the straight track from the *heel* of the switch to the point of the middle frog. The length of switch AD should conform to the

tabular values unless the throw is to be different from that assumed in the table. See § 195, 196 and 204 of the text.

TABLES XXIIA and XXIIB.—Contain the recommended standards of the American Railway Engineering Association for frogs and split switches. Offsets are given for locating the lead curves.

TABLE XXIII.—Contains the squares, cubes, square roots, cube roots, and reciprocals of numbers from 1 to 1054. Its use may be greatly extended by observing that if any number is multiplied by n its square is multiplied by n^2, its cube by n^3, and its reciprocal by $\frac{1}{n}$.

TABLE XXIV.—**The logarithm** of a number consists of two parts, a whole number called the *characteristic*, and a decimal called the *mantissa*. All numbers which consist of the same figures standing in the same order have the same mantissa, regardless of the position of the decimal point in the number, or of the number of ciphers which precede or follow the significant figures of the number. The value of the characteristic depends entirely on the position of the decimal point in the number. It is always one less than the number of figures in the number to the left of the decimal point. The value is therefore diminished by one every time the decimal point of the number is removed one place to the *left*, and *vice versa*. Thus

Number.	*Logarithm.*
13840.	4.141136
1384.0	3.141136
138.40	2.141136
13.84	1.141136
1.384	0.141136
.1384	−1.141136
.01384	−2.141136
.001384	−3.141136
etc.	etc.

The mantissa is always positive even when the chara istic is negative. We may avoid the use of a neg characteristic by arbitrarily adding 10, which ma lected at the close of the calculation. By this m

Number.	*Logarithm.*
1.384	0.141136
.1384	9.141136
.01384	8.141136
.001384	7.141136
etc.	etc.

No confusion need arise from this method in finding a number from its logarithm; for although the logarithm 6.141136 represents either the number 1,384,000, or the decimal .0001384, yet these are so diverse in their values that we can never be uncertain in a given problem which to adopt.

The table XXIV contains the mantissas of logarithms, carried to six places of decimals, for numbers between 1 and 9999, inclusive. The first three figures of a number are given in the first column, the fourth at the top of the other columns. The first two figures of the mantissa are given only in the second column, but these are understood to apply to the remaining four figures in either column following, which are comprised between the same horizontal lines with the two.

If a number (after cutting off the ciphers at either end) consists of not more than four figures, the mantissa may be taken direct from the table; but by interpolation the logarithm of a number having six figures may be obtained. The last column contains the average difference of consecutive logarithms on the same line, but for a given case the difference needs to be verified by actual subtraction, at least so far as the last figure is concerned. The lower part of the page contains a complete list of differences, with their multiples divided by 10.

To find the logarithm of a number having six figures. Take out the mantissa for the four superior places directly from the table, and find the difference between this mantissa and the next greater in the table. Add to the mantissa taken out the quantity found in the table of proportional parts, opposite the difference, and in the column headed by the fifth figure of the number; also add one tenth the quantity in the column headed by the sixth figure. The sum is the mantissa required, to which must be prefixed a decimal point and the proper characteristic.

Example.—Find the log of 23.4275.

For 2342 mantissa is	369587
For diff. 185 col. 7	129.5
For diff. 185 col. 5	9.2
Ans. For 23.4275 log is	1.369726

The decimals of the corrections are added together to etermine the nearest value of the sixth figure of the mantissa.

To find the number corresponding to a given ogarithm. If the given mantissa is not in the table, find the one next less, and take out the four figures corresponding to it; divide the difference between the two mantissas by the tabular difference in that part of the table, and annex the figures of the quotient to the four figures already taken out. Finally, place the decimal point according to the rule for characteristics, prefixing or annexing ciphers if necessary. The division required is facilitated by the table of proportional parts, which furnishes by inspection the figures of the quotient.

Example.—Find the number of which the logarithm is 8.263927

		8.263927
First 4 figures 1836 from		263873
	Diff.	54.0
Tabular diff. = 236	∴ 5th fig. = 2	47.2
		6.80
	6th fig. = 3	7.08

Ans. No. = .0183623 or 183,623,000.

The number derived from a six-place logarithm is n reliable beyond the sixth figure.

At the end of the Table XXIV is a small table of logarith of numbers from 1 to 100, with the characteristic prefix for easy reference when the given number does not exc two digits. But the same mantissas may be found in larger table.

TABLE XXV.—**The logarithmic sine, tang etc.,** of an arc is the logarithm of the natural sine, tan etc., of the same arc, but with 10 added to the char istic to avoid negatives. This table gives log sines, tan sines, and cotangents for every minute of the qua Ith the number of degrees at the left side of the pa

to be read the minutes in the left-hand column; with the degrees on the right-hand side are to be read the minutes in the right-hand column. When the degrees appear at the top of the page the top headings must be observed, when at the bottom those at the bottom. Since the values found for arcs in the first quadrant are duplicated in the second, the degrees are given from 0° to 180°. The differences in the logarithms due to a change of 1″ in the arc are given in adjoining columns.

To find the log sin, cos, tan, or cot of a given arc. Take out from the proper column of the table the logarithm corresponding to the given number of degrees and minutes. If there be any seconds multiply them by the adjoining tabular difference, and apply their product as a correction to the logarithm already taken out. The correction is to be *added* if the logarithms of the table are increasing with the angle, or *subtracted* if they are decreasing as the angle increases. In the first quadrant the log sines and tangents increase, and the log cosines and cotangents decrease as the angle increases.

Example.—Find the log sin of 9° 28′ 20″.

Log sin of 9° 28′ is	9.216097
Add correction 20 × 12.62	252
Ans.	9.216349

Example.—Find the log cot of 9° 28′ 20″.

Log cotan of 9° 28′ is	10.777948
Subtract correction 20 × 12.97	259
Ans.	10.777689

To find the angle or arc corresponding to a given logarithmic sine, tangent, cosine, or cotangent. If the given logarithm is found in the proper column take out the degrees and minutes directly; if not, find the two consecutive logarithms between which the given logarithm would fall, and adopt that one which corresponds to the least number of minutes; which minutes take out with the degrees, and divide the difference between this logarithm and the given one by the adjoining tabular difference for a quotient, which will be the required number of seconds.

logarithms to six places of decimals the quotient is iable beyond the tenth of a second.

mple.—9.383731 is the log tan of what angle?

Next *less* 9.383682 gives 13° 36′

Diff. 49.00 ÷ 9.20 = 05″.3

Ans. 13° 36′ 05″.3

xample.—9.249348 is the log cos of what angle?

Next *greater* 583 gives 79° 46′

Diff. 235 ÷ 11.67 = 20″.1

Ans. 79° 46′ 20″.1

The above rules do not apply to the first two pages of this table (except for the column headed cosine at top) because here the differences vary so rapidly that interpolation made by them in the usual way will not give exact results.

On the first two pages, the *first* column contains the number of seconds for every minute from 1′ to 2°; the minutes are given in the *second*, the log sin in the *third*, and in the *fourth* are the last three figures of a logarithm which is the difference between the log sin and the logarithm of the number of seconds in the first column. The first three figures and the characteristic of this logarithm are placed, once for all, at the head of the column.

To find the log sin of an arc less than 2° given to seconds. Reduce the given arc to seconds, and take the logarithm of the number of seconds from the table of logarithms, and *add* to this the logarithm from the fourth column opposite the same number of seconds. The sum is the log sin required.

The logarithm in the fourth column may need a sligh interpolation of the last figure, to make it correspond closel to the given number of seconds.

Example.—Find the log sin of 1° 39′ 14″.4.

1° 39′ 14″.4 = 5954″.4 log 3.774838

add $(q - l)$ 4.685515

Ans. log sin 8.460353

Log tangents of small arcs are found in the same way, only taking the last four figures of ($q - l$) **from the** ***fifth*** **column.**

Example.—Find the log tan of 0° 52′ 35″.

52′ 35″ = (3120″ + 35″) = 3155″ log 3.498999
add ($q - l$) 4.685609

Ans. log tan 8.184608

To find the log cotangent of an angle less than 2° given to seconds. Take from the column headed ($q + l$) the logarithm corresponding to the given angle, interpolating for the last figure if necessary, and from this *subtract* the logarithm of the number of seconds in the given angle.

Example.—Find the log cotan of 1° 44′ 22″.5.

$q + l$ 15.314292
6240″ + 22″.5 = 6262.5 log 3.796748

Ans. 11.517544

These two pages may be used in the same way when the given angle lies between 88° and 92°, or between 178° and 180°; but if the number of degrees be found at the *bottom* of the page, the title of each column will be found there also; and if the number of degrees be found on the *right-hand* side of the page, the number of minutes must be found in the right-hand column, and since here the minutes increase upward, the number of seconds on the same line in the first column must be *diminished* by the odd seconds in the given angle to obtain the number whose logarithm is to be used with ($q \pm l$) taken from the table.

Example.—Find the log cos of 88° 41′ 12″.5.

($q - l$) 4.685537
4740″ − 12″.5 = 4727.5 log 3.674631

Ans. 8.360168

Example.—Find the log tan of 90° 30′ 50″.

$q + l$ 15.314413
1800″ + 50″ = 1850″ log 3.267172

Ans. 12.047241

To find the arc corresponding to a given log si cos, tan, or cotan which falls within the limits the first two pages of Table XXV. Find in t proper column two consecutive logarithms between whi the given logarithm falls. If the title of the given functi is found at the top of that column read the degrees from t top of the page; if at the bottom read from the bottom.

Find the value of $(q - l)$ or $(q + l)$, as the case m require, corresponding to the given log (interpolating f the last figure if necessary). Then if q = given log a l = log of number of seconds, n, in the required arc, we ha at once $l = q - (q - l)$ or $l = (q + l) - q$, whence n easily found.

Find in the first column two consecutive quantities betwe which the number n falls, and if the degrees are read fro the *left-hand* side of the page, adopt the *less*, take out t minutes from the second column, and take for the secon the difference between the quantity adopted and the numb n. But if the degrees are read from the *right-hand* side the page, adopt the *greater* quantity, take out the minut on the same line from the right-hand column, and for t seconds take the difference between the number adopt and the number n.

Example.—11.734268 is the log cot of what arc?

$q + l$ 15.314376
q 11.734268

$\therefore$ $n =$ 3802″.8 3.580108
For 1° adopt 3780. giving 03′

Difference 22″.8

Ans. 1° 03′ 22″.8 or 178° 56′ 37″.2.

Example.—8.201795 is the log cos of what arc?

$q - l$ 4.685556
q 8.201795

$\therefore$ $n =$ 3282″.8 3.516239
For 89° adopt 3300. giving 05′

Difference 17″.2

Ans. 89° 05′ 17″.2 or 90° 54′ 42″.8.

TABLE XXVI.—Contains logarithmic versed sines and external secants for every minute of the quadrant, with the differences of the same corresponding to a change of 1 second in the arc or angle. Interpolation for seconds is made in the same manner as with log sines of the preceding table, except on the first two pages. For angles less than 4° the differences vary so rapidly that interpolation by direct proportion will not give exact values.

On the first two pages the column headed $q - 2l$ contains the difference between the log versed sine (or log ex secant) of an arc and *twice* the logarithm of the number of seconds in the same arc. The characteristic, and first three decimals (9.070) are common to all the logarithms in these columns up to 3° 19′ for log vers sines, where it changes to (9.069), as shown at the foot of the column; and up to 4° for log ex secants, where it changes to (9.071). At the point of change a cipher is replaced by the mark * to call attention.

To find the log vers sin, or log ex sec of an angle given to seconds. Reduce the angle to seconds, take the logarithm of this number, multiply it by 2, and add the product to the logarithm in the column $(q - 2l)$ found opposite the given angle. The log $(q - 2l)$ should be corrected by interpolation for the fractional part of a minute in the given angle.

Example.—What is the log ex secant of 2° 14′ 43″.7?

$$
\begin{array}{rr}
2^\circ\,14'\,43''.7 = 8040'' + 43.7 = 8083''.7 \ \log & 3.907610 \\
 & 2 \\
\hline
2l & 7.815220 \\
(q - 2l) & 9.070398 \\
\hline
\textit{Ans.}\ \therefore\ q & 6.885618
\end{array}
$$

To find the arc corresponding to a given log vers, or log ex sec. Find in the column of log vers, or log ex sec the two values between which the given log falls, and take out from the column $(q - 2l)$ the logarithm corresponding to the given log (interpolating for the value of the last figure if necessary). Subtract this from the given logarithm and divide by 2. The quotient is the logarithm of the number of seconds in the required arc.

Example.—7.344728 is the log vers of what arc?

		q	7.344728
3° 48′ +		$(q-2l)$	9.069960
			2)8.274768
	13720″.9	∴ l	4.137384
	13680.		
Ans.	3° 48′ 40″.9		

To find the log ex sec of an arc greater tha 88° given to seconds. Take from the column (q + the logarithm corresponding to the given arc, interpolati for the fraction of a minute. From this subtract the lo arithm of the number of seconds in the *complement* of t given arc.

Example.—What is the log ex sec of 88° 24′ 20″.5?

For 88° 24′	$q+l$	15.302183
Correction $129 \times \frac{20.5}{60} =$		44
	$q+l$	15.302227
Comp. 88° 24′ 20″.5 = 5739″.5	log	3.758874
	Ans. log ex sec	11.543353

To find the angle corresponding to a give log ex sec when the angle is greater than 88 Find in the table the two consecutive log ex secants betwe which the given one falls, and then find by interpolati the value of the log ($q + l$) corresponding to the given l ex sec and subtract the latter from it. The difference w be the logarithm of the number of seconds in the *compleme* of the required angle, which is then easily found.

Example.—11.924368 is the log ex sec of what arc?

Given log ex sec	11.924368		
Next less	11.918290	$q+l$	15.309225
Diff.	6078		
Correction	$= \frac{9352 - 9225}{29141 - 18290} \times 6078 =$		71
		$q+l$	15.309296
Given log ex sec			11.924368
	0° 40′ 26″.2 = 2426″.2	∴ log	3.384928

Ans. 89° 19′ 33″.8.

TABLE XXVII.—Contains natural sines and cosines, to five places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly proportional to the difference of consecutive values in the table; positive for sines, negative for cosines.

TABLE XXVIII.—Contains natural tangents and cotangents to five places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly proportional to the difference of consecutive values in the table; positive for tangents, negative for cotangents.

TABLE XXIX.—Contains natural versed sines and external secants to five places of decimals for every minute of the quadrant. Corrections for fractions of a minute are made directly proportional to the difference of consecutive values. They are positive in every case.

TABLE XXX.—Contains the number of cubic yards contained in prismoids of various side slopes, bases, and depths, as indicated by the title and the numbers in the first column. Each prismoid is supposed to have a uniform level cross-section throughout. These tables are chiefly useful in making up preliminary estimates from the profile, or in other cases where only approximate results are required. For monthly and final estimates more elaborate tables are required, such as are described in §§ 276, 277, 278 and 279 of the text.

To make an approximate estimate of quantities from a profile by use of Table XXX.—Select the proper column for base and slopes, and if the outline of a cut on the profile is roughly a four-sided figure, stretch a fine silk thread over the surface line to average it, note the depth from thread to grade line midway of the cutting, and multiply the tabular number opposite this depth by the average length of the cutting in stations of 100 feet. (By average length is meant the half sum of the length of the grade line in the cutting and of so much of the surface line as is covered by the thread.) If the area of a cutting as seen on the profile is approximately triangular, stretch an averaging line over each incline, and note the depth from the intersection of these lines to grade, and multiply the tabular number opposite this depth by one half the length of the cut measured on the grade line in stations. The resulti quantities will be slightly in excess if the ground is leve transversely, but may be too small if the transverse slop is steep, and cutting on the center line is small. In genera they furnish a good approximation. Quantities in embank ments may, of course, be found similarly. A cut or fill ma be divided on the profile into several portions, and th contents of each portion found separately if preferred.

The content of a prismoid, level transversely, but havin different end-depths, may be found correctly by this tabl thus: add together the quantities opposite each end-dept and four times the quantity opposite the half sum of th depths; multiply the sum by the length in feet, and divid by 600.

TABLE XXXI.—The volume of a triangular prism equal to the product of the area of the base and the altitud This, in cubic yards, for a length of 50 feet, is expressed b the formula, $S = \frac{50}{54}\,ba$, where b and a are the base an altitude of the triangular section. Any end area of a sectio of earthwork, whether three-level or irregular, may divided into a number of triangles, and the total volum of the solid between the sections may be considered as con posed of prisms with these triangles as bases. The mea area volume of a solid for 100 feet in length will be the su of the two 50-foot volumes. An example will illustrate th use of the table.

Example.—Given the following notes.

Sta. 28	$\frac{16.0}{+4.0}$	$+2.4$	$\frac{11.8}{+1.2}$
Sta. 27	$\frac{19.0}{+6.0}$	$+3.0$	$\frac{13.6}{+2.4}$

Base 20 feet, slope 1½ to 1.

Two methods might be used for the work. First, whe the section is divided into four triangles, and second, whe the area is composed of two triangles less a third triang which is formed by prolonging the side slope lines to the intersection. The former method will be used.

The volume for station 27 for length 50 feet is

$$\frac{50}{54}(3.0)(19.0 + 13.6) + \frac{50}{54}(6.0 + 2.4)(10)$$

Opposite H'g't. 3.0 under 3 take 10 × 8.333 = 83.330
" 2 " 1 × 5.556 = 5.556
" 6 " $\frac{1}{10}$ × 16.667 = 1.667

lso

Opposite H'g't. 8.4 " 1 " 10 × 7.778 = 77.780
the total volume for length 50 feet = 168.333

Similarly, the volume for station 28 for length 50 feet is

$$\frac{50}{54}(2.4)(16.0 + 11.8) + \frac{50}{54}(4.0 + 1.2)(10) = 109.927$$

The work may be somewhat shortened by not strictly bserving the terms "height" and "width," since $\frac{0}{4}(32.6)(3.0)$ is the same in value as the expression given bove for station 27. This is obtained by entering the table nce, considering 32.6 as the height, and 3.0 as the width.

The mean area volume will then be

168.333 + 109.927 = 278.26, or 278.3 cubic yards.

The prismoidal correction may be applied to this result, ıus giving the prismoidal volume. The explanation of ıe method of finding this correction is given below.

TABLE XXXII.—This table gives the correction to be pplied to the mean area volume to give the prismoidal olume. The table is based on the formula

$$C = \frac{1}{3.24}(d - d')(D - D')$$

here d and d' are the center heights, and D and D' the istances between slope stakes at two adjacent stations.

Using the same data as given under the explanation of able XXXI, the value of the correction is

$$C = \frac{1}{3.24}(3.0 - 2.4)(32.6 - 27.8) = \frac{1}{3.24}(0.6)(4.8)$$

From Table XXXI find

opposite $D - D'$, 4.8 under 6 take $\frac{1}{10}$ × 8.889 = 0.9

The mean area volume from the same example was 278.3 ubic yards. The prismoidal volume will then be 278.3 − .9 = 277.4.

The volume for any other distance between sections may e found by taking the proper percentage of the volume for 100 feet distance, the multiplication being made the application of the prismoidal correction.

TABLE XXXIII.—Contains the recommendations American Railway Engineering Association on min lengths of spirals for various speeds and degrees of cur

TABLE XXXIV.—This table exhibits the features original spiral from which others may be derived. degree of curve is assumed to vary with each chord, and this the central spiral angle up to any point is easily de and also the inclination of any chord to the main ta drawn through S as meridian.

The coordinates, x and y of any spiral point, referr S as an origin, are obtained by summation of depa and latitudes of the intervening chords. These are with great precision, so that their continuous summ may not lead to any error in the final result.

Finally, the deflection angle from the tangent at S t spiral point is found by dividing x by y for that giving the tangent for the deflection. All these resul tabulated, as also the radius corresponding to the of curve, the chord length being 100 feet, as with an ord circular curve. These deflections remain the same fo spiral whatever. The variation is made in the length chord, and the values of x, y, and R_s vary directly wit chord length. The value of D_s is derived from R_s. table is made the basis of the tables which follow.

TABLE XXXV.—This gives the list of deflections to of the spiral points, not only from S (as in the preceding t but also from each one of the twenty other spiral in the system.

TABLE XXXVI.—This gives a series of spirals of ass chord length from 10 to 50, with the corresponding of D_s, y and x. In any case only so many chords will be as will lead up to (and not beyond) the selected deg curve which is to follow the spiral. The terminal L of any spiral indicates the values of x and y to be in connection with it.

TABLE XXXVII.—This table gives certain trigonor functions of the spiral angle s for convenient referen sing spiral formulas.

Table XXXVIII.—This table, as a companion to XXXVI, gives the spiral tangents and long chord for the same set of spirals, and also the coordinates, p and q, from S. Read the note at the head of the table.

Table XXXIX.—Gives a selection of circular curves, varying in degree from 1° 40′ to 35° and suitable spirals to be used with each, and also the coordinates p and q from S of the point A' where the particular curve would meet a parallel tangent. Generally there is considerable choice in the length of spiral.

Table XL.—Exhibits a series of special cases where it is required to replace an existing simple curve by another with spirals so chosen that the length of the track shall not be sensibly altered. The middle offset, h, is given, also x, and the distance $d = AS$, from old P.C. to P.S., and the new degree of curve, D'.

The series embraces curves of 2°, 4°, 8°, and 16°, and central angles from 10° to 80° inclusive, and will be found very useful in solving problems of this sort.

Table XLI.—Contains concise statements of such geometrical truths as are applicable to the various discussions in this volume. References are given to Davies' Geometry, in which the demonstrations of the propositions may be found.

Table XLII.—Contains all the formulas necessary to the solution of any plane triangle; also, a select list of miscellaneous formulas. A few formulas with respect to the versed sine and external secant are new.

Table XLIII.—Contains a list of the more important formulas derived in the text. A large number of special formulas on simple curves are given, for which no derivations are included. The notation is the same as that used in the text.

Table XLIV.—Contains a variety of useful numbers and formulas. The logarithms are here given to seven places of decimals

TABLE XLV. Deflections for the ten-chord spiral. Transit at S. These deflections are computed by eq. (K), using the coordinates of the several points, and are rigidly correct. They are independent of the length of spiral but depend on the spiral angle, S. When the required value of S is not found in this table interpolation may be made. The first deflection is always S divided by 300.

TABLE XLVI.—Coefficients for deflections from local tangent at any point. At whatever chord point the transit is set, the vernier reads zero upon the local tangent through that point. For any other chord point multiply the first deflection, i_1, (Table XLV) by the coefficients (Table XLVI) found in the column of the same number as the transit point. When the product is for a point more than five points from the transit it is subject to a small correction found in Table XLVII. This correction is on the line of the spiral angle S, and in the column of the point observed, *counting from the transit as zero.* The correction is *minus* for sights made toward L and *plus* for sights made toward S.

By the use of the tenth column a series of deflections are obtained which, after correction, serve to locate the spiral from L to the tangent at S. This method is more convenient than that given in § 232i.

Example.—Given a spiral of 360 feet connecting with a 20° curve, to find the deflections from the common tangent at L'.

By eq. (C), $S = 36°$, $i_1 = 7.2'$, $c = 36$ feet.

Multiply i_1 by coefficients in last column of Table XLVI for these deflections, the first five of which, being small, need no correction. The last five products and their corrections (from Table XLVII) and the required deflections are as follows:

Point.	Product.	Correction.	Deflection.
4	17° 16.8′	+ 00.1′	17° 16.9′
3	19 19.2	+ 00.3	19 19.5
2	21 07.2	+ 00.6	21 07.8
1	22 40.8	+ 01.2	22 42.0
S'	24 00.0	+ 02.3	24 02.3

Note that point 4 is the sixth sight from L', hence the correction is found in column 6, line of 36°. The others follow.

Example. The same spiral with transit at point 8.

There is no correction prior to point 2, which is the sixth rom the transit.

Point.	Product.	Correction.	Deflection.
2	12° 57.6′	+ 00.1′	12° 57.7′
1	14 16.8	+ 00.3	14 17.1′
S'	15 21.6	+ 00.6	15 22.2

Example.—The same spiral with transit at point 3.

Find coefficients in column 3, Table XLVI. Here point L s the seventh from the transit, and looking toward L; hence he correction is *minus* 00.3. The others, after point 9, need o correction.

Point.	Product.	Correction.	Deflection.
L	13° 26.4′	− 00.3′	13° 26.1′
9	10 48.0	− 00.1	10 47.9

Table XLVII.—Corrections in minutes for the larger eflections. Eq. (H) is convenient for computing a deflecion, i, but being an approximate formula, the result is subect to a small correction when it exceeds 5°, or when the oint observed is more than five chord points from the transit orrections are given to two decimal places, but only the rst decimal usually need be quoted. The application of hese corrections is explained above in connection with able XLVI. Observe that in Table XLVI the columns are umbered from the tangent point S, but in Table XLVII they re numbered from the position of the transit.

Table XLVIII.—Spiral parts for given degrees of curve. his table presents a list of twenty curves, between 1° and 0° inclusive, combined with from 16 to 28 spirals for each urve, giving for each length of spiral, the spiral angle S, the inal coordinates, X and Y, the long chord, C, also the coordiates, p and q of A' on the circular curve. When a selection f curve and spiral can be made from this table these quanties can be taken out at once.

Table XLIX.—Coefficients of L for spiral parts for iven values of S. Spirals having the same central angle, , are similar, whatever be their length, and so their parts are roportional to their length. Either part divided by the ength gives a coefficient for finding that part in terms of L hen S is given. By eq. (C) $L=\frac{200S}{D}$. If S is not given exactly in the table the required coefficient may be fo interpolation.

The coordinates, p and q, being functions of bot and curve, require two coefficients to express their v shown in the table. But if X and Y are already k will be more convenient to find p and q by eq. (P).